Chapter 2

Main Actors of Innovation

The way innovation systems are defined has major implications for the balance and mix of policies needed to improve innovation system performance and for the amount of communication and co-ordination required to create holistic innovation policies. To the extent that countries operate within the confines of a narrow "innovation system map" focused on science and technology and the formal R&D system, they are likely to be guided into making policy choices that optimise the formal part of the system at the expense of the whole. However, over the last decade or so, a broader perspective on innovation systems has emerged, which increasingly underpins attempts by governments to develop more holistic innovation and research policies.

With this broader perspective in mind, this chapter provides an overall assessment of the innovation and research activities of the business sector, the public science and education systems, and the stock and flow of human resources. It begins with the central actors in any well-functioning innovation system – business firms – and further explores explanations for low levels of R&D spending but also broadens the perspective on firm innovation by taking into account non-R&D and non-technological innovation. The chapter then considers the public-sector research system, starting with the public research centres (PRCs). This is followed by an exploration of Mexican higher education institutions, which perform the largest share of publicly funded R&D in Mexico and are responsible for tertiary education. A final section covers the human resource dimension of innovation.

2.1. Business sector

As noted in Chapter 1, levels of business enterprise R&D (BERD) in Mexico are very low by OECD standards but gradually rising. The latest innovation survey (ESIDET) paints a picture of Mexican enterprises increasingly undertaking R&D as part of their innovation activities. This section explores the relation between R&D spending by enterprises and the specialisation and structure of the Mexican economy. Innovation survey data are then used to illustrate the importance of non-R&D innovation for Mexican firms. Much of the section is devoted to a discussion of linkages between large and small firms and between industry and public science. A final section highlights the barriers facing innovating firms in Mexico.

2.1.1. Research in firms

Mexico has one of the lowest business R&D intensities in the OECD area (Table 2.1), although it more than doubled over 2000-05 to 0.23%. Almost half of the R&D carried out in Mexico in 2005 was performed in business firms, again a major increase compared to the level five years earlier. This increased activity has been accompanied by marked increases in the number of researchers working in business enterprises[1] and by an almost five-fold increase over the six years to 2008 in the number of firms registered in the National Register of Scientific and Technological Firms and Institutions (RENIECYT)[2] (Figure 2.1).

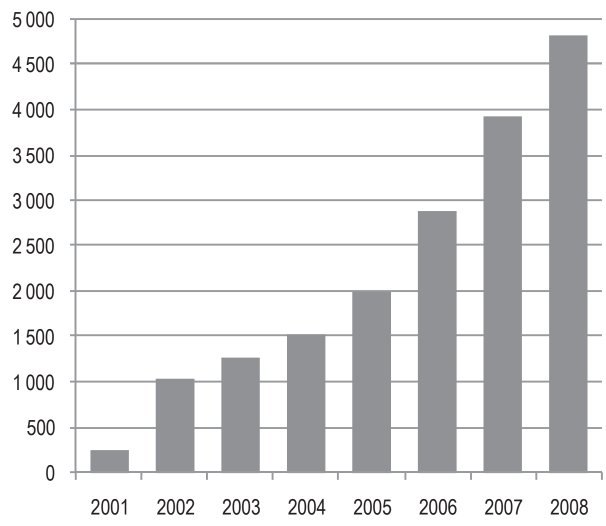
Table 2.1. Main R&D indicators for the Mexican business sector, 1999-2006

	2000	2001	2002	2003	2004[1]	2005
% of GERD financed by industry	29.5	29.8	34.7	34.7	44.0	46.5
% of GERD performed by business sector	29.8	30.3	34.1	34.6	46.6	49.5
BERD (million current PPP USD)	998	1 100	1 421	1 518	2 380	2 927
BERD (% of GDP)	0.10	0.11	0.14	0.14	0.20	0.23
Business enterprise researchers (FTE)	n.a.	n.a.	n.a.	8 663	20 958	24 367
% of BERD financed by industry	90.1	89.8	97.6	96.8	92.9	92.6
% of BERD financed by government	9.3	9.6	1.5	2.6	5.4	5.7
% of BERD financed by other national sources	0.1	0.0	0.4	0.6	0.1	0.3
% of BERD financed by abroad	0.5	0.6	0.5	0.0	1.6	1.4

1. Break in series with previous year for which data are available.

Source: OECD Main Science and Technology Indicators.

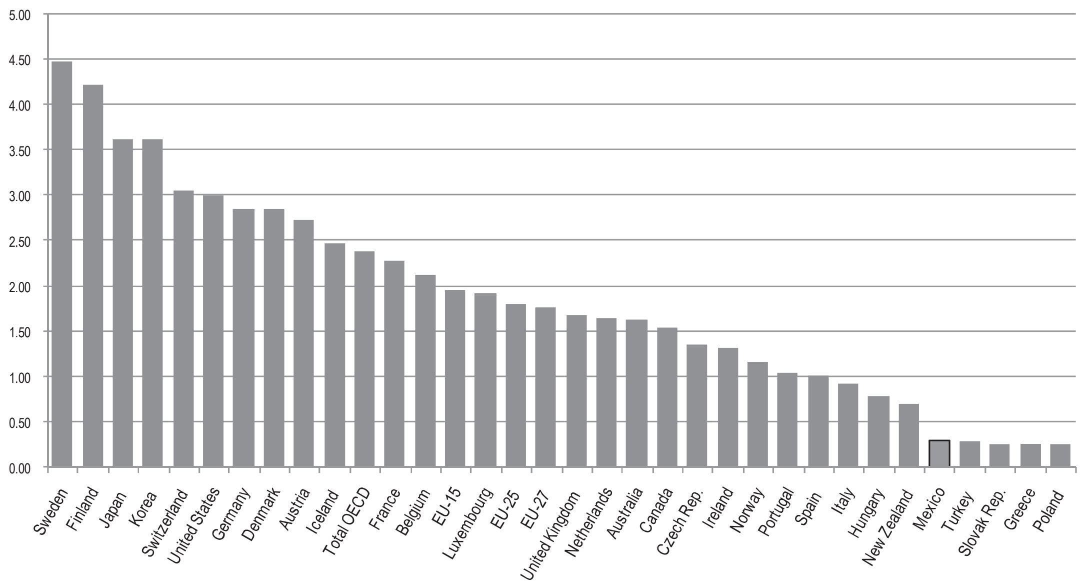
Figure 2.1. Firms and institutions registered in the RENIECYT, 2001-07



Source: CONACYT.

Despite these seemingly promising developments, the level of BERD as a percentage of value added in industry remains one of the lowest in the OECD (Figure 2.2). This low R&D intensity can be largely attributed to the country's industrial structure, which is dominated by micro-enterprises and SMEs operating mostly in services and low- and medium-technology (LMT) manufacturing sectors. It is well known that small firms are less likely to conduct R&D than their larger counterparts; the same is true for firms in the services and LMT manufacturing sectors. As Figure 2.3 shows, a little over 40% of Mexican BERD conducted in firms employing more than 50 persons is spent in smaller firms (with 50-250 employees), a comparatively high proportion. Larger firms play a less prominent role in Mexico than in many other OECD countries, particularly the larger ones, such as Germany, Japan and the United States, where large firms often play a leading role in structuring markets, in carrying out large-scale innovations and even in co-ordinating smaller firms.

Figure 2.2. BERD as a percentage of value added in industry, 2007[1]

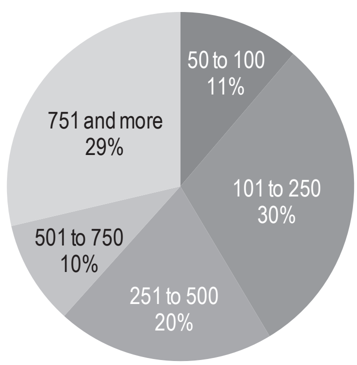


1. Or nearest available year.

Source: OECD Main Science and Technology Indicators.

Figure 2.3. BERD by firm size in Mexico, 2005

Number of employees



Source: Background report, CONACYT.

Table 2.2 indicates that in 2005, around 18% of Mexican BERD was spent in the services sector, a figure comparable to that of the European Union but a little more than half that of the United States. This would seem to be in line with Mexico's larger than average manufacturing sector. Table 2.3 completes the picture of BERD, showing that despite the traditional low levels of R&D spending in LMT manufacturing sectors in OECD countries, the Mexican LMT sector accounts for the highest proportion of BERD in the OECD area. Furthermore, high-technology industries account for one of the lowest proportions of BERD. These figures are to be expected, given the dominance of LMT sectors in the Mexican economy.

Table 2.2. BERD by industry in Mexico, 2005

In millions of constant 2006 MXN

Industry	Amount
Agriculture	3
Mining	80
Manufacturing	15 112
Food, beverages and tobacco	2 900
Textiles, clothing, fur and leather	951
Wood, paper, printing and publishing	252
Coke, petroleum, nuclear fuel, chemicals & rubber and plastic products	4 954
Non-metallic mineral products	861
Base metals	284
Manufactured metal products (except machinery and equipment)	1 241
Machinery, equipment, instruments and transport equipment	3 602
Furniture and other manufactures not specified elsewhere	66
Electricity, gas and water supply	88
Construction	2
Services sector	3 407
Total	**18 692**

Source: Background report, CONACYT.

2.1.2. Technological innovation

According to the results of the 2006 Encuesta sobre Investigación y Desarrollo Tecnológico (ESIDET) innovation survey (Box 2.1), a quarter of surveyed firms indicated that they had undertaken some type of technological innovation in 2004-05. Although not directly comparable, data from a similar survey conducted in 2001 show there to have been no increase in the proportion of innovative firms in recent years (Table 2.4). In line with the results of innovation surveys carried out in many other countries, the 2001 survey indicates that larger firms tend to be more innovative. This pattern breaks down in the 2006 survey, however, with medium-sized firms apparently the most innovative.

Table 2.3. Percentage of BERD performed in different industries in OECD countries, 2006[1]

	High-technology industries	Medium high-technology industries	Medium-low-technology and low-technology industries	Service industries
Australia	10.0	11.7	16.9	39.7
Austria	31.0	27.8	12.9	27.4
Belgium	41.2	23.7	15.7	17.0
Canada	32.4	9.1	11.0	41.9
Czech Republic	22.3	35.6	8.7	31.8
Denmark	39.4	16.2	8.5	35.0
Finland	63.8	13.5	12.1	8.2
France	44.6	29.9	11.5	8.4
Germany	29.6	52.2	8.3	9.4
Greece	21.8	13.8	17.2	44.9
Hungary	53.7	16.0	6.6	21.4
Iceland	25.0	6.9	5.7	59.7
Ireland	48.0	9.0	9.3	33.6
Italy	33.1	29.1	8.0	26.8
Japan	44.7	40.4	2.9	10.4
Korea	53.8	27.9	8.3	7.1
Mexico	**9.7**	**21.8**	**35.1**	**32.6**
Netherlands	40.9	27.8	8.5	17.4
Norway	12.6	16.3	12.6	50.3
Poland	13.9	23.7	9.1	50.6
Portugal	17.6	17.6	10.9	44.0
Spain	20.5	18.8	15.1	41.8
Sweden	38.7	29.8	5.2	24.8
Turkey	16.3	42.0	14.5	25.8
United Kingdom	49.0	18.8	7.6	23.2
United States	40.3	16.6	6.4	36.1
EU15	38.7	34.9	9.2	15.0

1. Or nearest available year.

Note: High-technology industries include aerospace; office and computing equipment; pharmaceuticals; radio, TV and communication equipment; medical, precision and optical instruments. Medium-high-technology industries include motor vehicles; chemicals; electrical machinery; other transport; machinery and equipment. Medium-low-technology and low-technology industries include rubber and plastics; non-metallic mineral products; shipbuilding; ferrous and non-ferrous metals; metal products; petroleum; other manufacturing industries.

Box 2.1. The 2006 ESIDET innovation survey

Like the well-known Community Innovation Surveys (CIS) of the European Commission, the 2006 ESIDET innovation survey of Mexican firms was based on the second edition of the OECD *Oslo Manual* for collecting and interpreting technological innovation data (OECD, 1996). Accordingly, the survey used two definitions of innovation:

1. *Technological product innovation* relates to the use of ideas and concepts to create new products which are then introduced on the market to offer something new or improved. A *technologically new* product may be developed based on radically new technologies or result from existing technologies used in new ways or may make use of new knowledge. A *technologically improved* product is one whose performance is significantly improved by utilising new components or materials or through integration of new subsystems.

2. *Technological process innovation* relates to the implementation and/or adoption of new or significantly improved production methods. This may involve changes in equipment, human resources, working methods or a combination of these. Such methods must be aimed at producing technologically new or improved products that cannot be produced using conventional production methods.

Non-technological innovation was not covered by the survey, although this is likely to be a significant phenomenon in Mexican firms. In fact, non-technological innovation is increasingly recognised as an important driver of transformative change in enterprises across all OECD countries. According to the third edition of the *Oslo Manual* (OECD, 2005), it can be broken down into two main components: organisational innovation, which refers to important changes in the organisational structure or the administration of an enterprise; and marketing innovations, which cover important changes in the design or packaging of products or important changes in sales or distribution methods.

The 2006 innovation survey was administered as a module of the biennial ESIDET survey of firms and covered the years 2004 and 2005. It follows a similar innovation survey module administered in 2001. A total of 16 398 firms answered the 2006 innovation module of the survey and are classified according to size (determined by number of employees: 50-100, 101-250, 251-500, 501-750, and 751 or more) and industry branch.

Source: CONACYT (2007), *Informe general del estado de la ciencia y la tecnología* 2007.

While not directly comparable with the results of the ESIDET survey, data from the fourth Community Innovation Survey (CIS4) for the 27 members of the European Union (EU27) for the period 2002-04 show that 40% of European firms surveyed had engaged in innovation – a significantly greater proportion of firms than in Mexico.[3] The distribution of innovative firms in European countries varies widely, however, with 65% of German enterprises active in innovation compared to only 16% in Bulgaria. In fact, the share of innovative enterprises in Mexico is broadly comparable to the levels of new EU member states.

Table 2.4. Share of Mexican companies undertaking technological innovation

As indicated by the ESIDET surveys and compared with the latest European survey

Company size	2001 survey	2006 survey	CIS4 survey
50-100	23	22	53
101-250	21	29	
251-500	34	28	71
501-750	41	26	
751+	43	20	
Total	**26**	**25**	**40**

Note: CIS4 total includes data for smaller firms (10-49 employees).

Source: CONACYT and Eurostat (2008).

Although the share of innovative firms is similar in both the 2001 and 2006 ESIDET surveys, there is a striking difference in firms' expenditures by type of innovation activities (Table 2.5). While less than 10% of innovative firms' expenditures on innovation were devoted to R&D in 2001, this share reached more than 40% in the 2006 survey. Even if the data in these two surveys are not fully comparable, the magnitude of the shift suggests a considerable increase in firms' R&D activities; this is confirmed by the BERD data presented earlier. This picture varies considerably among sectors, however. For example, continuing low R&D spenders include firms in the following sectors: clothing and leather (0.2% of innovation expenditures), financial intermediation (10.6%), carbon, petroleum derivatives and nuclear energy (14.6%), mining (19.2%), and textiles (20.2%). By contrast, the share of R&D expenditures in innovative activities is high in firms in the following sectors: office equipment, accounting and computing machinery (73.9%), non-metallic minerals (66.9%), agriculture (65.0%), and food and drink (63.6%).

Table 2.5. Firms' expenditures by type of innovative activity in Mexico

Percentage of total investment in innovation

Expenditures	2001 survey	2006 survey
Acquisition of machinery and equipment related to innovation in products and processes	66.2	39.7
Acquisition of other technologies related to innovation in products and processes	7.5	8.9
Industrial design and/or other expenditures to initiate production of new or improved products	8.3	3.6
Training programmes linked to innovation activities	2.7	2.8
Expenditures in marketing linked to innovative technologies	6.8	2.5
R&D	8.5	42.5
Total	100.0	100.0

Source: ESIDET results, CONACYT.

In spite of the overall increase in R&D activities, the majority of expenditures on innovative activities are not used to perform R&D. Instead, the acquisition of machinery and equipment (almost 40%) and other technologies (almost 9%) related to innovation in products and processes account for almost half of all innovation expenditures. This is hardly surprising given Mexico's industrial ecology and its "catching-up" status. Indeed, analytical work on innovation survey data in Europe (Arundel *et al*., 2008) suggests that R&D is correlated with certain firm characteristics. For example, non-R&D innovators are likely to be smaller firms active in LMT manufacturing and services sectors and located in countries with trailing or lagging average innovative capabilities. Innovation processes in such firms are often less formal and more related to modification and incremental change, design and process optimisation.

It is important to recall that acquisition of machinery and the like should not be viewed as somehow inferior to R&D or in need of "correction". While it is widely thought that most productivity improvements and performance outcomes are due to innovative activities based on R&D (particularly in high-technology industries), innovation theory and empirical studies suggest that such assumptions are unfounded. Recent analysis of European innovation data (Arundel *et al*., 2008) shows little difference in performance, as measured by a change in revenue, between innovative firms that do and do not perform R&D. This confirms that innovation rests not on discovery but on learning, which can be based on activities that recombine or adapt existing forms of knowledge (Smith, 2002). Box 2.2 provides a few examples of innovation approaches that do not necessarily involve R&D.

Box 2.2. Non-R&D performing innovators

How do firms that do not perform R&D innovate? The innovation literature points to four main methods:

1. *Technology adoption*: Firms can acquire innovative products and processes from sources external to the firm, with little or no further work required. For example, a computer assembler can purchase faster hard drives or wireless cards from specialist firms for inclusion in a notebook computer, or a food processing firm can purchase improved packaging equipment. CIS data used by Evangelista and Mastrostefano (2006) show that the acquisition of new machinery and equipment is one of the most common innovation activities across firms. Similarly, firms can acquire ideas for organisational innovations from other firms.
2. *Minor modifications or incremental changes* to products and processes, including the use of engineering knowledge (Kline and Rosenberg, 1986). Modifications can be made to both purchased products and processes or to technologies previously developed by the firm itself. These innovation activities are particularly common for process innovation (Evangelista *et al*., 2002; Nascia and Perani, 2002). Lhuillery and Bogers (2006) estimate that 15% of overall cost reductions are from incremental innovations made by employees to production processes. Incremental change can depend on learning by doing, as a firm gets better at what it already does (Cohen and Levinthal, 1989).
3. *Imitation, including reverse engineering*: Many activities to replicate products or processes that are already available, including some solutions to circumvent a patent (Kim and Nelson, 2000), do not require R&D. This method of innovating may be especially common in less developed countries or for innovations that are not patentable.
4. *Combining existing knowledge in new ways*: This can include some types of industrial design and engineering projects (Grimpe and Sofka, 2007; Huston and Sakkab, 2006). The Italian "informal learning systems" are used by SMEs in traditional industries and mechanical and electrical/electronics sectors to create new products (Evangelista *et al*., 2002). These systems build on tacit knowledge, engineering skills and cumulative learning processes that are located in the system rather than in a specific firm (Gottardi, 1996). Informal contacts and highly skilled and mobile personnel move tacit knowledge from firm to firm.

There are also situations in which a firm adopts solutions developed by users (with users possibly doing some unreported R&D work). Von Hippel (2005) argues that user innovation is much more widespread than earlier thought. It thrives when there are methods for sharing information and breaking down a problem into components (*e.g.* innovation toolkits). These enable users to innovate without new R&D and improve the ability of users to combine and co-ordinate their efforts (*e.g.* over the Internet). User innovation can also serve as an important source of solutions for firms. Von Hippel calls users' ability to develop what they need instead of buying what is available the "democratisation of innovation".

Source: Arundel *et al*. (2008), "Neglected Innovators – How Do Innovative Firms That Do Not Perform R&D Innovate?", INNO-Metrics Thematic Paper, MERIT, University of Maastricht.

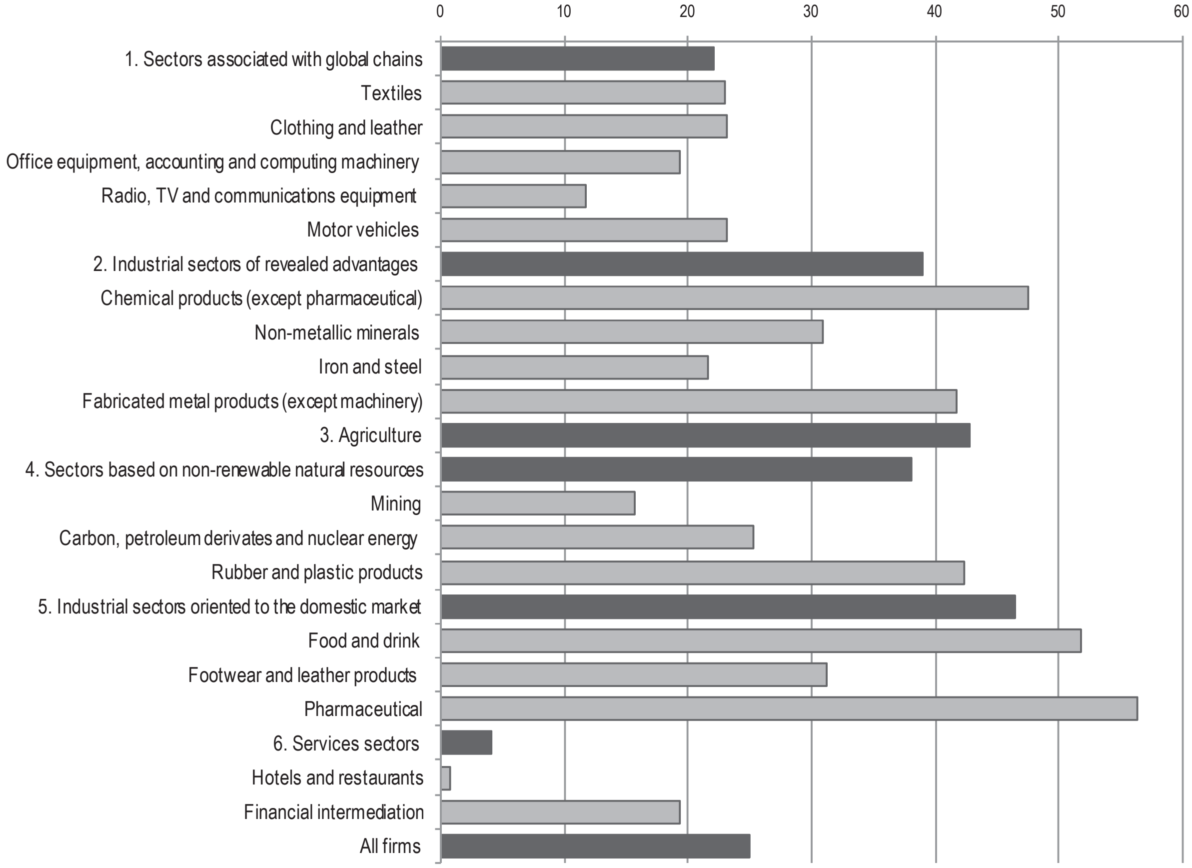
Table 2.6. Different "types" of business sector and their characterisation

Sector types	Main sectors/products	Type of firms	Main states
1. Sectors associated with global chains	Automotive, electronics, office equipment, clothing	Subsidiaries, large domestic firms and some supplier SMEs	Chihuahua, Baja California, Jalisco, Edo México, Puebla, Aguascalientes, Guanajuato, Coahuila and Querétaro
2. Industrial sectors with revealed comparative advantages	Iron and steel, glass, chemicals	Large domestic firms, some subsidiaries, and supplier SMEs	Nuevo León, Querétaro, DF
3. Sectors with revealed comparative advantages based on agriculture, stockbreeding, forest and fishing	Tequila, coffee, vegetables, shrimp	Large domestic firms, commercial producers of different sizes, associations and co-operatives of producers	Jalisco, Sinaloa, Sonora, Guanajuato, Querétaro, Chiapas, Veracruz
4. Sectors based on non-renewable natural resources	Petroleum derivates, petrochemicals and mining	Large domestic private firms and state-owned firms	Tabasco, Veracruz, Tamaulipas
5. Industrial sectors oriented to the domestic market	Cement, pharmaceuticals, food, footwear, software	Large domestic firms, subsidiaries, and traditional and high-technology SMEs	DF, Jalisco, Edo México, Guanajuato
6. Services sectors	Tourism, banking	Large domestic firms, subsidiaries, SMEs and associations	Baja California Sur, Guerrero, Yucatán, Quintana Roo, Jalisco, Oaxaca, Nuevo León, DF

Source: Background report, CONACYT.

Among Mexican firms with innovative projects, 82% were from manufacturing and 17% from services (a further 1% were from other sectors, including agriculture). As business firms face different scientific-technological challenges depending on the types of market in which they operate, their ownership structure, their size, and their area of business activity, it is useful to construct a typology in order to take such distinctions into account. Therefore, Table 2.6 sets out six "types" of productive profile which are selectively used in subsequent analysis of ESIDET survey data. While it would be wrong to assume there is homogeneity within each sectoral "type" (Figure 2.4), the groupings are nevertheless useful to explore some of the dependencies between innovative activities and factors such as firm size, ownership and market. For example, Figure 2.4 shows that services firms are far less likely to engage in technological innovation than their manufacturing counterparts – a not unexpected result. In the services sector, financial intermediation firms are an important exception owing to their high levels of acquisition of software linked to technological innovation.

Figure 2.4. Percentage of innovative firms by sector in Mexico, 2004-05



Source: ESIDET results, CONACYT.

Results for other sectors are perhaps more surprising, at least on an initial viewing. For instance, agriculture is often thought of as a low-technology, low-innovation sector, yet the ESIDET data show that more than 40% of firms surveyed in the agricultural sector conducted some form of innovative activity in 2004-05. Moreover, more than 60% of innovation expenditures were devoted to R&D, one of the highest proportions among all sectors. However, this is less surprising when the types of firms surveyed are considered: suppliers of machinery, seed, fertiliser, animal feed, etc., all require R&D for their development.[4]

A further "surprise" concerns the apparently greater innovativeness of industrial firms serving largely domestic markets (Table 2.6. sector 5) than those associated with global value chains (sector 1). A phenomenon that may be similar was reported by Dussel Peters *et al.* (2007) using data from Mexico's 2004 economic census. Focusing more narrowly on R&D, the authors find a negative association between foreign direct investment (FDI) and expenditures on technological R&D by big manufacturing firms. Specifically, they use a typology of Mexico's large manufacturing firms – divided into three groups: *i*) those with FDI from 0.1% to 49%; *ii*) those with no FDI; and *iii*) those with an FDI share above 50% of its capital – to show that firms with no FDI have the highest R&D intensity, followed by those with more than a 50% FDI capital share and then those with less than 50%. This pattern is reproduced in two of the main FDI sectors in Mexico, automotive and electronics. Taken together, these results suggest that Mexican subsidiaries of overseas transnational corporations (TNCs) and the firms that supply them do not, on the whole, function as innovation platforms. This has implications for the potential of FDI to generate significant knowledge spillovers to the rest of the Mexican economy (see Box 2.3).

Box 2.3. Investment strategies of transnational corporations and the scope for knowledge spillovers

In spite of the many positive effects associated with FDI, it has largely failed to live up to expectations in terms of promoting the industrial and technological upgrading of Mexican firms through the generation of useful knowledge spillovers. A contributing factor is the nature of the corporate strategies of many investing TNCs. Dunning (1993) created a typology that distinguishes between four principal focal points of TNC operations from the perspective of corporate FDI strategies, as follows:

- *Natural-resource-seeking strategy*: firms that are motivated to invest abroad to acquire specific resources at a lower cost than could be obtained in their home country;
- *Market-seeking strategy*: firms that invest in a particular country or region in order to serve local markets;
- *Efficiency-seeking strategy*: firms that seek to rationalise their production, distribution and marketing activities through common governance of and synergy-building among geographically dispersed operations;
- *Technological/strategic-asset-seeking strategy*: firms that seek to promote their strategic objectives, for example, through the accumulation of technological capabilities.

In Mexico, strategic asset-seeking FDI is almost non-existent. Instead, most FDI comes from efficiency-seeking TNCs that establish platforms as part of their regional or international systems of integrated production. These local assembly operations of mainly US TNCs are primarily cost centres for high- and medium-technology manufacturing, such as automotive and electronics. Global competition in these industries obliges TNCs to search for lower-cost, large-scale production sites close to major markets for the labour-intensive aspects of their production processes. Mexico offers privileged access to the North American market through NAFTA and has therefore seen considerable levels of investment by US TNCs. As a result, Mexico's international competitiveness has improved dramatically, as measured by its increased market share of automotive and electronic products in the US market.

In the automotive industry mostly US FDI in new plants during the 1990s converted an uncompetitive industry focused on the national market into a highly competitive platform aimed at the North American market. Investment has been driven by proximity, lower salaries, and preferential market access through NAFTA, all in the context of increasing competition from Asian auto manufacturers. Between 1985 and 2002, the production capacity of the Mexican automotive industry rose from 400 000 to almost 2 million units. Exports rocketed from almost zero to about 1.4 million units with Mexican plants accounting for 14% of vehicle imports to North America.

However, TNC operations in Mexico focus on static rather than dynamic host country advantages (such as skilled human resources and local technology capabilities). As a result, the dependence of assembly operations on imported components means that local productive linkages are weak. This leads to very limited cluster formation and thus severe limits on the industrial and technological upgrading of the industry in Mexico. In other words, the overall impact of this "transnationalisation" process has been much less than expected in terms of "ripple effects" on the host economy and companies.

Source: Based on Mortimore (2006), "The Transnationalisation of Developing America: Opportunities and Challenges", ECLAC, Santiago.

Box 2.4. The automotive sector in Mexico: its importance, evolution and challenges

The automobile industry is the largest branch of Mexico's manufacturing. In 2005, the sector accounted for 15.1% of manufacturing GDP, 13.7% of manufacturing employment and close to 20% of manufactured exports. In the past decade, it has gone through several export phases, with vehicle and parts exports to the United States growing by an average of 21% from 1995 to 2000, before falling by an average of –2% between 2001 and 2005. In 2006, following a period of re-tooling, vehicle and vehicle part exports grew at 26%. Going forward, export growth will principally depend on the strength of the US market and also the auto product cycle. Part of the strong export growth in 2006 was due to an upswing in production from the launch of new models. Developments in the industry suggest that Mexico has a growing comparative advantage in auto manufacturing. In January 2005, the Ford Motor Company announced the shutdown of 12 of its plants in the United States by 2012. At the same time it projected an increase of its operations in Mexico. Today Mexico is exporting a range of higher value cars to the biggest markets in the world, while importing cheaper cars for domestic use.

Evolution

The development of the Mexican automobile sector has gone through periods of contrasting policies, from import substitution in the 1950s and 1960s to export promotion in the 1980s. The most important rules governing automobile exports are set out in NAFTA. In the case of new cars, NAFTA requires around 60% of the car to be produced in NAFTA countries in order for it to be exported from Mexico to the United States and Canada.

Over time different factors have determined the establishment of factories in certain regions of Mexico. Initially, car factories were established near Mexico City because of its large market. Later, the companies were established in the northern part of the country, close to in-bond industries (*maquiladoras*). There is evidence that this later localisation was due to productivity advantages rather than low wages. The more recent localisation of investments seems to be dictated by the systemic competitiveness that can be gained from the integration of car industries with large local supply chains. This is reflected in increasing regional specialisation in the north and two central areas of Mexico.

Challenges

One of the advantages that could be expected from FDI in the sector is the spillovers and linkages it can potentially generate for the Mexican economy, specifically through the development of chains of suppliers. However, this has so far been limited. The automobile sector has relied on large tier 1 suppliers from Canada, the United States or Mexico (direct suppliers to an auto manufacturer which are often involved in design and manufacture, but not marketing of final products), but it has only developed limited linkages with small Mexican suppliers for tiers 2 and 3 (sub-contracting manufacturers to tier 1 not normally involved in design). To enter the production chain, smaller suppliers have to comply with high international standards of quality and meet large production requirements. Up until now, low quality and limited flexibility and reliability, partly due to poor managerial skills, have been the main obstacle for smaller Mexican suppliers to develop and cluster with the car assembly plants. In this context, despite ongoing efforts, foreign direct investors have not been able to provide the much needed training and managerial skills that small suppliers need. In many cases, small suppliers do not qualify to tender for business (because they lack the sales volume or the necessary ISO quality ratings) and therefore cannot benefit from the knowledge that car factories can provide.

The challenge for Mexico is to continue to improve support strategies that will encourage a more integrated and deeper manufacturing base. There are many government policies aimed at helping small firms. To ensure that the policy mix is cost-efficient over the medium term, there needs to be greater co-ordination and systematic policy evaluation. For this to be possible, surveys and data collection about small firm performance have to be improved. See OECD (2007b) for a review of current SME policies in Mexico.

Source: OECD (2007), *Economic Surveys: Mexico*, OECD, Paris.

2.1.3. Linkages between large firms and small firms

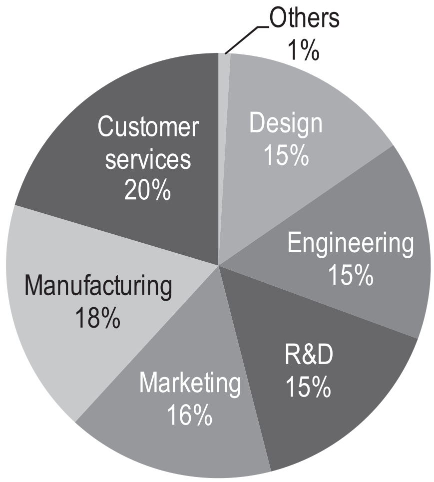
Knowledge spillovers from large firms to smaller ones occur when part of the knowledge generated by the larger organisation spills over its boundaries and becomes available to other organisations. Typical mechanisms include backward linkages to suppliers, human capital accumulation and mobility, and training effects. Of particular interest are backward linkages, which are widely lauded by proponents of FDI as the most important mechanism for knowledge spillovers. These tend to occur in two ways: either customer firms establish supportive linkages to supplier firms, increasing their capabilities directly; and/or customers put pressure on their suppliers to produce inputs that satisfy requirements of quality, quantity, delivery time and price, a mechanism that forces suppliers to improve quality and efficiency (Jordaan, 2005).

As Chapter 1 has pointed out, Mexico's industrial ecology is dominated by micro firms, with very few large or medium-sized firms. This structure limits the potential for the supply chain linkages that can help smaller firms to grow and increase their productivity. This has meant that Mexican firms have sometimes been unable to supply transnational corporations in the electronics and automobile sectors owing to a lack of scale and technical capabilities and quality. While links between foreign investors and their direct domestic suppliers (tier 1 suppliers) are reasonably strong, there are only weak links between the tier 1 suppliers and their generally smaller suppliers (tier 2 and tier 3 suppliers) (OECD, 2007a). Box 2.4 describes the automotive supply chain in Mexico.

2.1.4. Knowledge transfer through information sourcing and co-operation

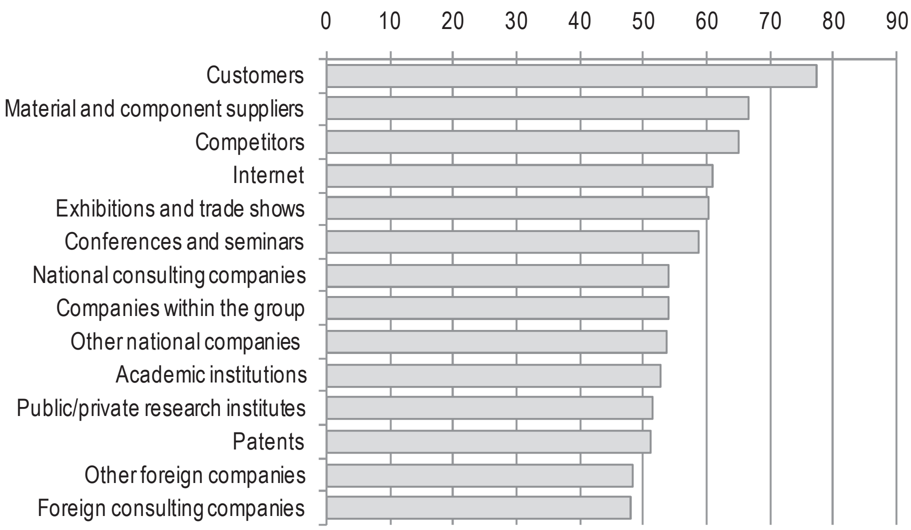
Firms' internal sources of innovation are not dominated by R&D departments as is sometimes mistakenly believed. In line with findings in many other countries, R&D departments are just one of many sources of innovation in Mexican firms and not the most important one (Figure 2.5). Customer services departments are more likely to be the source of innovations than any other department. This is not surprising given the well-known importance of customers and clients for innovation. Figure 2.6 shows in fact that the top three external sources of information for innovation are customers, suppliers and competitors. The importance of suppliers reflects the predominance of acquisition of machinery and equipment in Mexican innovation and probably accounts also for the popularity of exhibitions and trade fairs. In line with the results of innovation surveys conducted in other parts of the world, higher education institutions (HEIs) and public research centres (PRCs) are less likely sources of information for innovative Mexican enterprises.

Figure 2.5. Main "internal sources" of information for innovation in Mexico, 2004-05



Source: ESIDET results, CONACYT.

Figure 2.6. Main "external sources" of information for innovation in Mexico, 2004-05

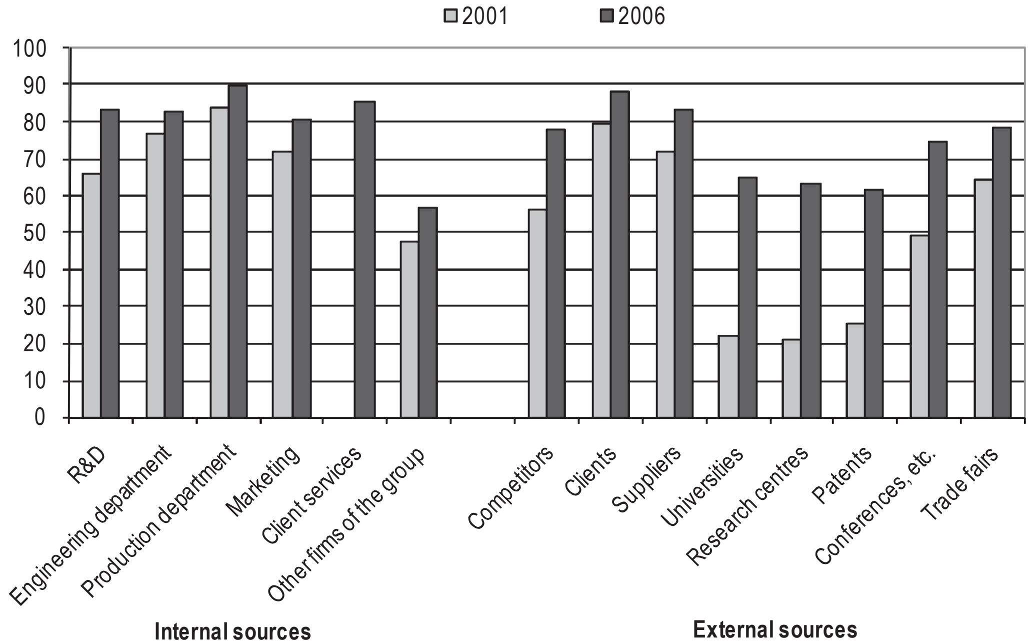


Source: ESIDET results, CONACYT.

Figure 2.7 compares the results of the 2001 and 2006 ESIDET surveys for the manufacturing sector and shows that firms report increases across all sources of innovation. The most dramatic increases involve HEIs and PRCs, which are reported by three times as many firms in 2006 than in 2001 to be sources of innovation information. This would seem to be a promising development that coincides with the growth of firms' own R&D activities.

Figure 2.7. Evolution of sources of innovation in Mexico between 2001 and 2006

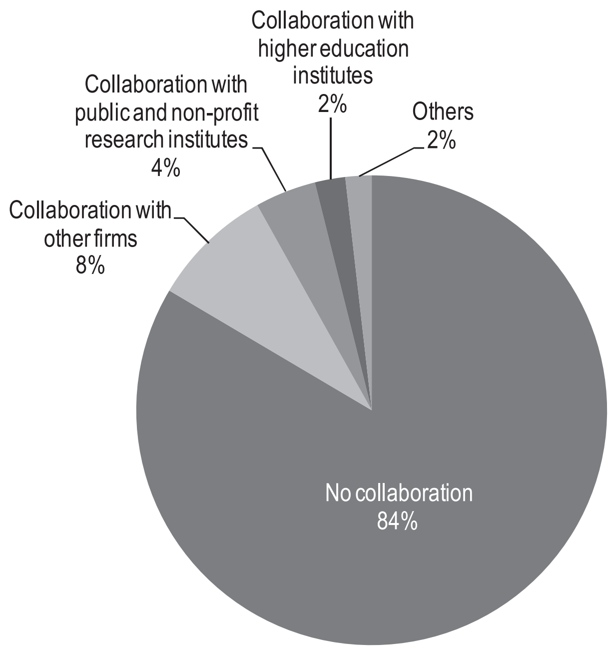
ESIDET surveys for the manufacturing sector



Source: EDISET results, CONACYT.

Figure 2.8. Innovation co-operation arrangements in Mexico, 2004-05

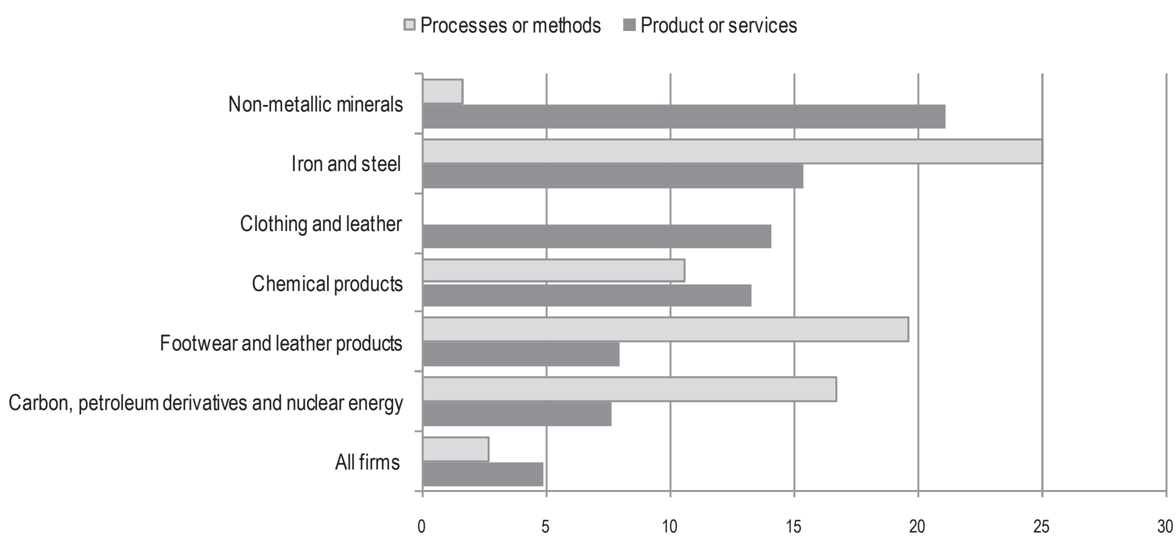
As a percentage of innovative enterprises



Source: EDISET results, CONACYT.

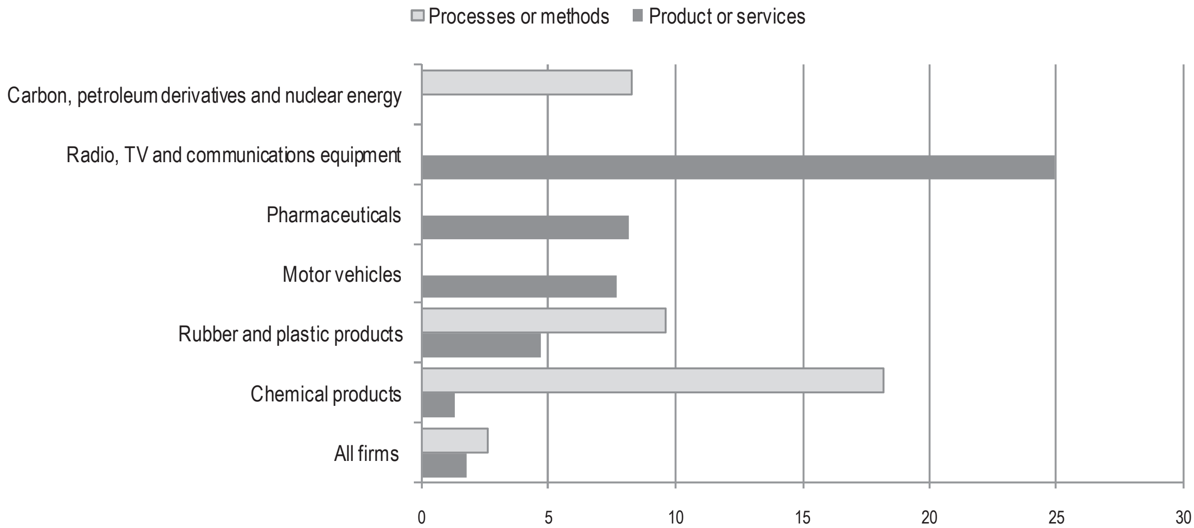
Data on co-operation for innovation is less encouraging, however. As Figure 2.8 shows, 84% of innovating firms reported no co-operation, a much higher proportion than in innovation surveys carried out in other countries. The pattern of co-operation is, on the other hand, largely what would be expected, with other firms by far the most popular partner, followed some way behind by PRCs and HEIs. The level of co-operation with the PRCs, at 4.2%, is not far from the level reported by CIS4 for the EU27 (5.6%). On the other hand, the level of co-operation with HEIs, at 2%, is especially low by international standards. These results are hardly surprising given the low levels of spending by Mexican firms on R&D, although there is some sectoral differentiation. For example, firms in industries such as textiles, radio, TV and communications equipment, iron and steel, carbon, petroleum derivatives and nuclear energy, and financial intermediation show well-above-average levels of co-operation with other firms. Similarly, firms in several sectors co-operate with PRCs and HEIs at well-above-average levels. Figure 2.9 highlights sectors in which the proportion of firms co-operating with PRCs is more than twice the average. It shows that co-operation is strongest in sectors with revealed comparative advantage (sector 2 in the typology in Table 2.6), as well as in a few sectors in which Mexico has traditionally been active, such as textiles, footwear and leather, and carbon, petroleum derivatives and nuclear energy. It is of course true that many of the PRCs were established to serve these very industries. The sectoral patterns of co-operation with HEIs are somewhat different. Figure 2.10 shows sectors in which the proportion of firms co-operating with HEIs is more than twice the average. They include high- and medium-high-technology sectors associated with global value chains, such as office equipment, accounting and computing machinery and motor vehicles; other high- and medium-high-technology sectors (*e.g.* pharmaceuticals); and medium-low-technology sectors based on non-renewable natural resources (sector 4 in the typology in Table 2.6). Some expected outcomes from industry-academic linkages are described in Box 2.5.

Figure 2.9. Proportion of firms co-operating with PRCs on innovation in Mexico, 2004-05



Source: ESIDET results, CONACYT.

Figure 2.10. Proportion of firms co-operating with HEIs on innovation in Mexico, 2004-05



Source: ESIDET results, CONACYT.

Box 2.5. Rationales and outcomes of industry-academic co-operation

An analysis of 11 collaborative projects between large Mexican firms and academic institutions illustrates characteristics of industry-academic linkages in Mexico. The actors involved are located in the states of Nuevo León and Coahuila, both of which are characterised by dynamic industrial development. These states also concentrate important public and private HEIs and PRCs. The cases relate to three fields with an interest in knowledge production or specific practical aspects: materials, polymers, and metallurgy. In six of the eleven cases analysed, the firm took the initiative in seeking out public academic centres, whether to collaborate on the formation of highly specialised human resources at the Master's level or to carry out research activities oriented towards new products and/or processes or to improve existing products and/or processes. In several cases, these objectives were achieved in a collective manner.

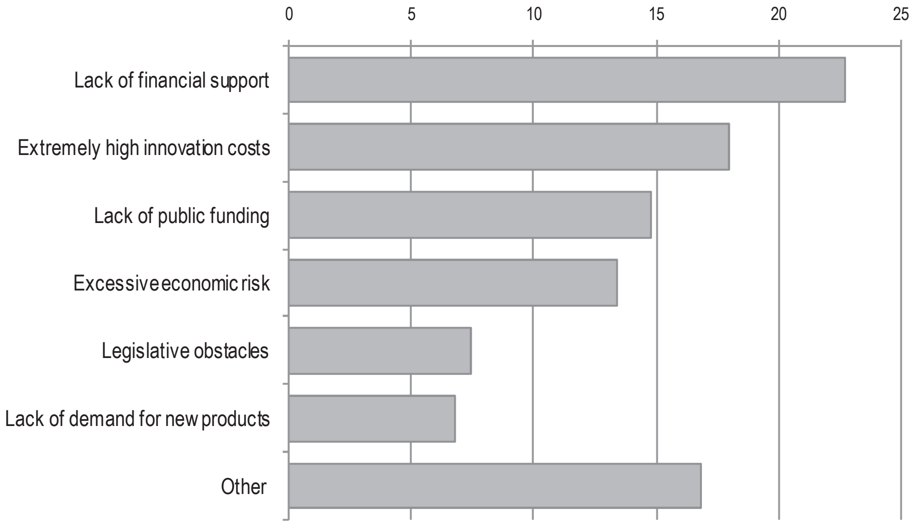
From the perspective of academia, more information was shared on procedures than on scientific and technical information. For the firms, technical and procedural and scientific information were equally important. One aspect that stands out in the analysis is the weight of codified and tacit knowledge in the projects. Codified knowledge was shared through technical laboratory reports of progress in the projects. Tacit knowledge was the most common form of exchange between academia and business enterprises. Here, ideas, skills, experiences, that is, individuals' abilities which have been acquired through formal and informal training, are generally exchanged in face-to-face relationships between network participants. Channels for exchange of knowledge emphasised by both actors include visits from academic investigators or firms' technicians, academic training courses, student residencies, and meetings of professional organisations.

For academia, the most important results of collaboration were related to the development of human resources, many of whom were taken on as employees once their studies were completed. Also important were improvements of processes and the solution of problems, the principal impacts of which for the firm were increased competitiveness through lower costs and higher quality. For the firms, only the training of human resources was considered important. These findings suggest that even though collaboration with academia was important for the firms, their perception was that it generated few results in terms of incremental and radical innovations and the solution of technical problems.

Source: Casas (2005), "Exchange and Knowledge Flows between Large Firms and Research Institutions", *Innovation: Management, Policy and Practice*, Special Issue on Innovation and Economic Development, Vol. 7, Nos. 2-3.

Figure 2.11. Risk factors for innovation projects in Mexico, 2004-05

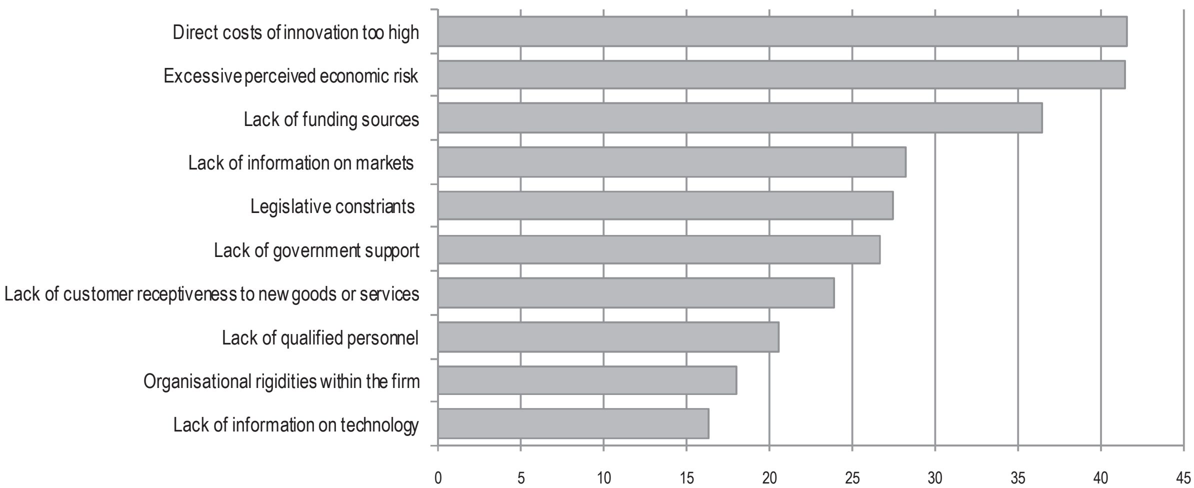
As identified by innovative firms, percentage



Source: ESIDET results, CONACYT.

Figure 2.12. Innovation constraints of medium and high importance in Mexico, 2004-05

Percentage

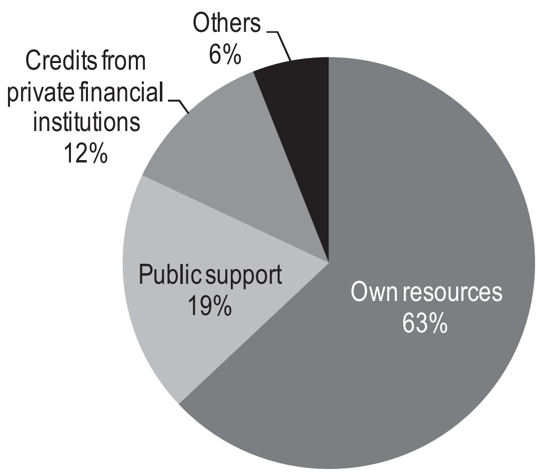


Source: ESIDET results, CONACYT.

2.1.5. Barriers to innovation

The firms that innovated, as identified in the 2006 ESIDET survey, also report several risk factors associated with their projects. As Figure 2.11 shows, these are dominated by concerns over financing; market concerns are lower on the list. This pattern was often reported when firms were asked about constraints to innovation. Figure 2.12 shows that various cost factors were the most often mentioned barriers and lack of information on technology the least mentioned. The pattern varies a little by sector. For example, firms from non-metallic minerals and financial intermediation report relatively fewer constraints in all categories, while firms from the radio, TV and communications equipment sector report constraints well above the average for all sectors. Firms from motor vehicles and pharmaceuticals face far fewer problems in securing funding sources. On the whole, these results confirm firms' difficulties for financing innovation, as highlighted in Chapter 1. Accordingly, the majority of firms' innovation financing had to be found from own resources (63%), with firms reporting just 12% coming from private financial institutions, a proportion even lower than the 19% provided by the public sector (Figure 2.13).

Figure 2.13. Sources of finance for innovation activities among innovative firms in Mexico, 2004-05



Source: ESIDET results, CONACYT.

2.2. Public research centres

Public research centres (PRCs) are an important part of the Mexican research system; they performed around 23% of Mexican gross domestic expenditure on R&D (GERD) in 2005. They are parastatal entities which have been granted a certain level of autonomy by presidential decree as stipulated by the Science and Technology Law (STL) and other regulations. As such, they are autonomous in terms of budget management, as well as the management of technical, operative and administrative aspects. There are two sets of PRCs: those supervised by CONACYT, the national council for science and technology, which account for about one-third of PRC research activity, and those supervised by other ministries which account for the remainder.

Table 2.7. Public research centres supervised by CONACYT

Natural sciences and mathematics	
CIAD	Centro de Investigación en Alimentación y Desarrollo, A.C.
CIBNOR	Centro de Investigaciones Biológicas del Noroeste, S.C.
CICESE	Centro de Investigación Científica y de Educación Superior de Ensenada, B.C.
CICY	Centro de Investigación Científica de Yucatán, A.C.
CIMAT	Centro de Investigación en Matemáticas, A.C.
CIMAV	Centro de Investigación en Materiales Avanzados, S.C.
CIO	Centro de Investigaciones en Óptica, A.C.
INECOL	Instituto de Ecología, A.C.
INAOE	Instituto Nacional de Astrofísica, Óptica y Electrónica
IPICYT	Instituto Potosino de Investigación Científica y Tecnológica, A.C.
Social sciences and humanities	
CIDE	Centro de Investigación y Docencia Económicas, A.C.
CIESAS	Centro de Investigaciones y Estudios Superiores en Antropología Social
CENTRO GEO	Centro de en Geografía y Geomática "Ing. Jorge L. Tamayo", A.C.
COLEF	El Colegio de la Frontera Norte, A.C.
COLMICH	El Colegio de Michoacán, A.C.
COLSAN	El Colegio de San Luis, A.C.
ECOSUR	El Colegio de Frontera Sur
MORA	Instituto de Investigaciones Dr. José Maria Luis Mora
Technology development	
CIATEC, A.C.	Centro de Innovación Aplicada en Tecnologías Competitivas
CIATEJ	Centro de Investigación y Asistencia en Tecnología y Diseño del Estado de Jalisco, A.C.
CIATEQ, A.C.	Centro de Tecnología Avanzada
CIDESI	Centro de Ingeniería y Desarrollo Industrial
CIDETEQ	Centro de Investigación y Desarrollo Tecnológico en Electroquímica, S.C.
CIQA	Centro de Investigación en Química Aplicada
COMIMSA	Corporación Mexicana de Investigación en Materiales, S.A. de C.V.
FIDERH	Fondo para el Desarrollo de Recursos Humanos
INFOTEC	Fondo de Información y Documentación para la Industria

Source: CONACYT.

The CONACYT PRCs are a set of 27 research institutes grouped into three main scientific and technological areas: ten research centres cover mathematics and the natural sciences; eight conduct research in social sciences and humanities; and eight specialise in innovation and technology development (Table 2.7). A further centre is dedicated to providing financial support for postgraduate studies. According to their mission statement, their main goals are as follows:

- diffuse science and technology methods and findings to society at large;
- promote local technology development and foreign technology adaptation to local conditions;
- innovate in the creation, assimilation, application and development of scientific and technological knowledge;
- build strong linkages between S&T activities and the social and productive sectors in order to solve social and productive problems;
- facilitate the private sector's contribution to the development of science and technology by creating appropriate mechanism and incentives;
- strengthen students' scientific and technological skills by integrating them into scientific and technological research activities;
- increase institutional research capacities in science, technology and the humanities;
- promote a scientific, technological and humanistic culture as a key part of Mexican society.

The PRCs are engaged not only in research, but also in training and extension activities, each of which is outlined further below. Given their emphasis on diffusion and adaptation and on local development, 75% of the main activities of the CONACYT PRCs were conducted outside of the Mexico City area in 2006. Figure 2.14 shows the distribution of CONACYT PRCs across Mexico. The rationale is to ensure a significant distribution of knowledge in different regions of the country – through scientific and technological work – and to maximise the impacts of projects and the multiplier effects of spending.

Figure 2.14. Locations of CONACYT PRCs

Source: CONACYT.

In addition to the CONACYT-supervised PRCs, several ministries have their own research centres, most of which were founded during a period of public sector expansion (1940-80). The initial goal assigned by the government to these institutes was to provide innovation and technological developments to other public organisations and companies related to energy, agriculture, health, natural resources and the environment. Table 2.8 lists the most important institutes.

Table 2.8. Some of the main PRCs administered by ministries

Ministry of Energy (SENER)	• The Electrical Research Institute (IIE), • Mexican Institute of Petroleum (IMP) • Research Institute for Nuclear Research (ININ)
Ministry of Agriculture, Livestock, Rural Development, Fishing and Food (SAGARPA)	• Institute for Forestry and Farming Research (INIFAP) • Mexican Institute for Water Technology • College of Postgraduates
Ministry of Health (SSA)	• National Institute for Public Health (INSP) • National Institute of Cardiology (INC) • The Paediatrics Institute (IP) • Salvador Zubiran National Nutrition Institute (INNSZ) • 16 other centres and research institutes in the health sector

2.2.1. Research activities of PRCs

The PRCs performed around 23% of Mexico's total R&D activities during 2005. This translates into around 45% of the research effort of the public research sector, the rest being taken up by higher education institutions. International comparisons of government expenditures on R&D (GOVERD) – which represent the greatest share of PRCs' R&D activities – show Mexican spending to be relatively low at 0.10% of GDP (Figure 2.15). Moreover, as Table 2.9 shows, the level of GOVERD declined sharply at the start of the 2000s although it has since stabilised. Such low proportions of GERD spent in the government sector are normally associated with a prominent role for higher education R&D (as in Sweden and the United Kingdom) and/or an absence of defence R&D (as in Belgium and Ireland). While both of these conditions apply to some extent in Mexico, the low levels of GOVERD can be better ascribed to the generally low levels of R&D spending by the Mexican government.

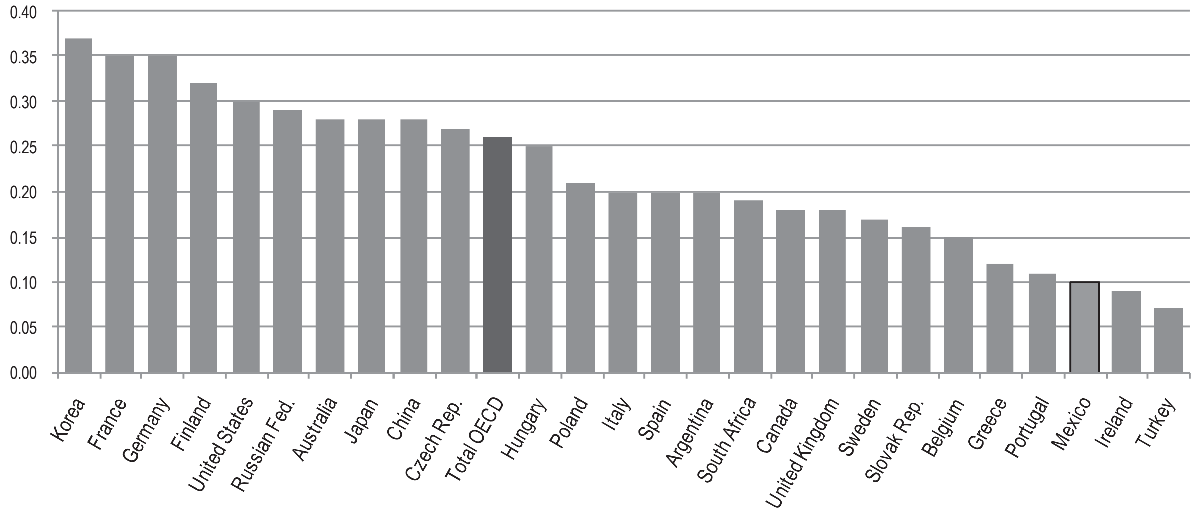
Table 2.9. GOVERD indicators for Mexico, 1999-2005

	1999	2001	2003	2004	2005
GOVERD (% of GDP)	0.18	0.14	0.10	0.10	0.10
GOVERD (USD millions, current PPP)	1 577	1 418	1 148	1 233	1 308
Government researchers (FTE)	7 540[1]	n.a.	6 397	6 754[1]	6 589[1]

1. National estimate.

Source: OECD Main Science and Technology Indicators.

Figure 2.15. GOVERD as percentage of GDP in selected countries, 2006[1]

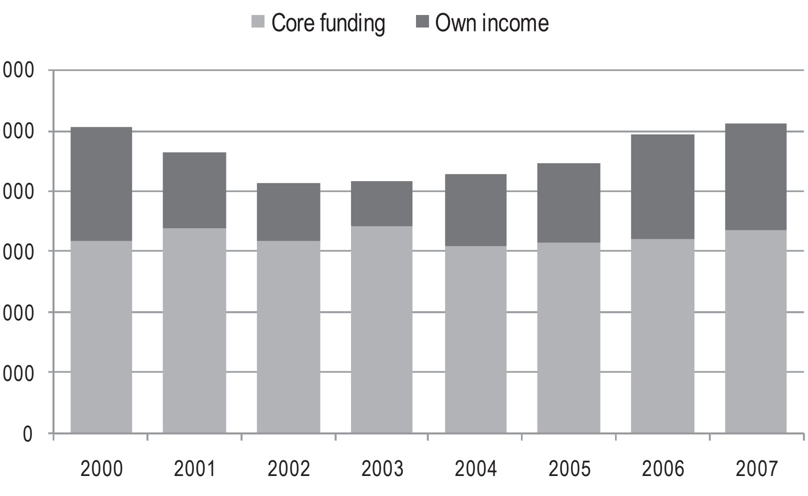


1. 2005 data for Mexico and South Africa.

Source: OECD Main Science and Technology Indicators.

Figure 2.16. Budget of CONACYT PRCs

MXN millions at 2007 prices

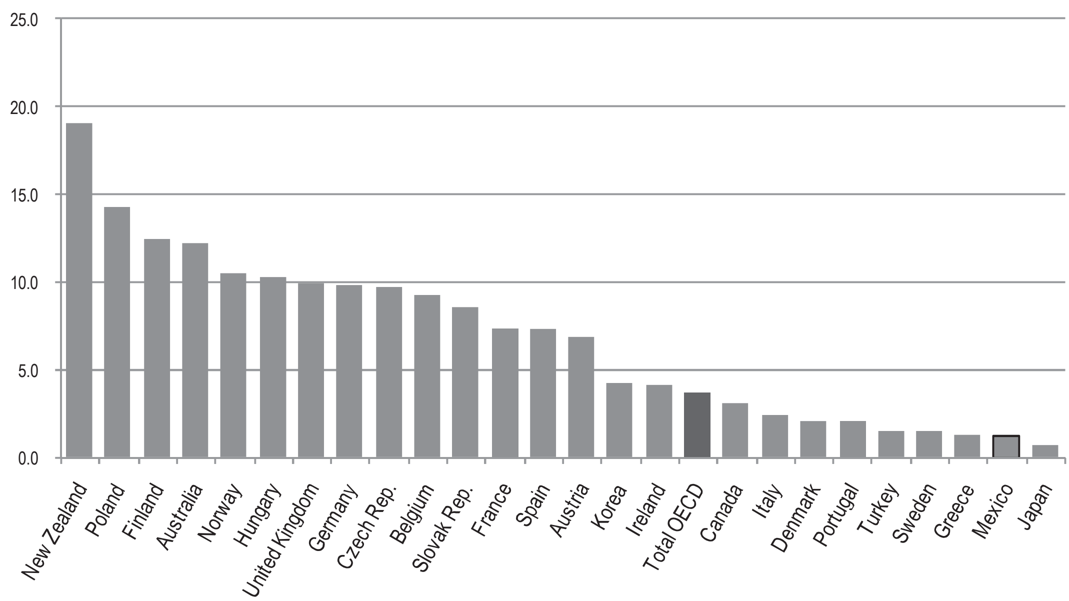


Source: CONACYT.

In 2007, the total budget of the CONACYT PRCs was estimated to be MXN 5.1 billion (Figure 2.16). Around two-thirds of the budget comes from CONACYT core funding, although the level varies considerably among the PRCs. The centres principally generating their own income from selling products and services to the public and private sectors were COMIMSA and INFOTEC. Each acquired around half of its funding in this way, followed closely by CIATEQ with 40%. In fact, these three centres accounted for almost 40% of the total income generated by the 27 CONACYT PRCs, with the majority of PRCs obtaining less than 10% of their funding in this way. These figures reflect changes in funding allocation arrangements – away from institutional funding and towards more competitive funding – which have led many CONACYT PRCs to adopt a more market-oriented approach in their strategic decisions concerning their research activities in order to increase their co-operation with the private sector and other institutions to which they provide technological services. They also reflect the premium given to projects involving co-operation between public research institutions and enterprises in submissions for financial support to CONACYT and other funding bodies such as the Ministry of Economy. A particular example is the increased share of projects involving co-operation with PRCs among those supported by the Economia-CONACYT S&T Fund for economic development. They reflect the fact that CONACYT PRCs are not a homogeneous set, as some have as their core mission the promotion of scientific activities in various disciplines or socio-economic areas, while others are more specifically oriented towards technology development and diffusion, generally along sectoral lines. These differences are reflected in their financing structure, with the latter able to count more on self-financing through the provision of technological services.

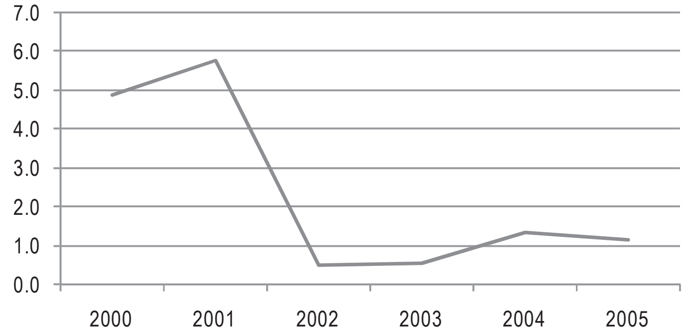
Across all of Mexican GOVERD – including research performed in a wider array of institutes than those supervised by CONACYT – the share of income accruing from the business sector, a mere 1.2% in 2005, is low by international standards (Figure 2.17) and appears to have been on a downward trajectory in recent years (Figure 2.18). This suggests that the sector as a whole largely fails to function as a provider of applied research for Mexico's business sector.

Figure 2.17. Percentage of GOVERD financed by industry in selected OECD countries, 2005



Source: OECD Main Science and Technology Indicators.

Figure 2.18. Percentage of Mexican GOVERD financed by industry, 2000-05



Source: OECD Main Science and Technology Indicators.

As Table 2.10 shows, the number of researchers (full-time equivalent – FTE) working in the sector has declined less sharply than the overall budget. The CONACYT PRCs employed 4 664 R&D personnel (FTE) in 2006, of which 2 006 were researchers and 2 658 were technicians and assistants (Table 2.10). The centres' researcher population represents less than one-third of all government researchers and a little less than 10% of the total number of public-sector researchers in Mexico. Of the 2 006 researchers, 1 436 hold doctorates, 356 hold a master's degree, and 212 are educated to the bachelor level. In other words, over 70% of the CONACYT researchers have a PhD, a proportion that compares very favourably internationally for public research institutes but suggests a rather academic orientation. This is perhaps confirmed by the fact that almost 60% of CONACYT researchers are registered in the SNI (Figure 2.19), a proportion in line with the overall picture across the Mexican public sector research base.

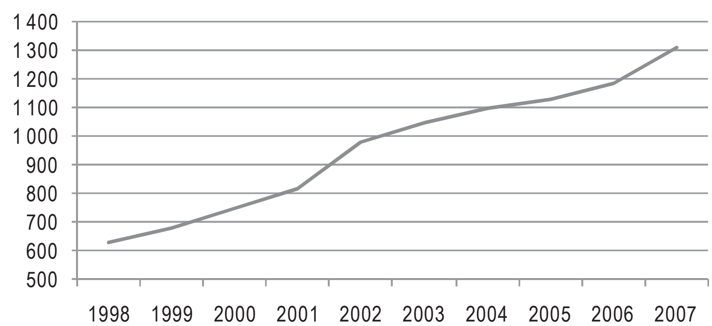
Table 2.10. Employees at CONACYT research centres, 2006

Full-time equivalent

Research staff			Non-research staff			Total
Researchers	Technicians and assistants	Sub-total	Administration and support	Other	Sub-total	
2 006	2 658	4 664	1 751	444	2 195	**6 859**

Source: CONACYT.

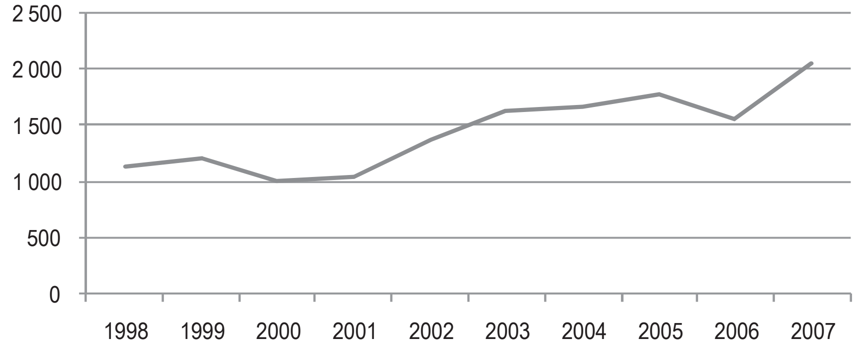
Figure 2.19. Number of SNI members in CONACYT PRCs, 1998-2007



Source: CONACYT.

A traditional indicator of research productivity is the number of journal articles generated by researchers. More than 2 000 journal articles were authored by CONACYT PRC researchers in 2007, three-quarters of which were published in international journals. As Figure 2.20 shows, the number of journal articles produced has climbed steadily, roughly doubling over the past decade. Similar patterns can be seen in other countries and reflect in part the increasing use of publication data in evaluations of researcher and institute performance. In the case of the CONACYT PRCs, the financial and reputational rewards associated with SNI membership have strongly helped increase publication rates.

Figure 2.20. Published journal articles from CONACYT PRC researchers, 1998-2007

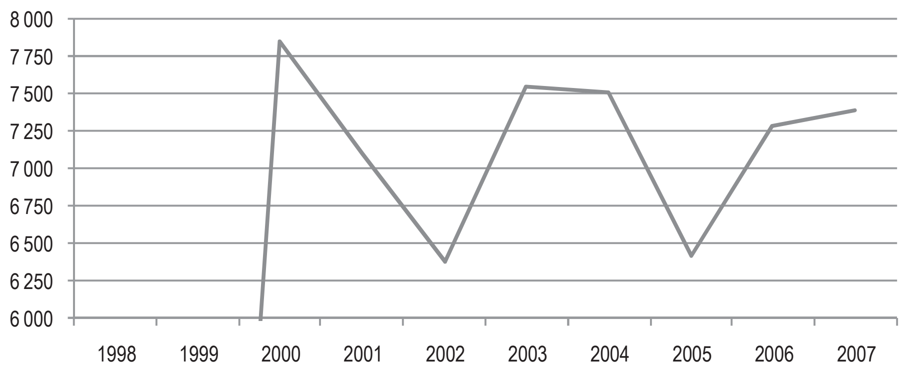


Source: CONACYT.

2.2.2. Training, extension and commercialisation activities

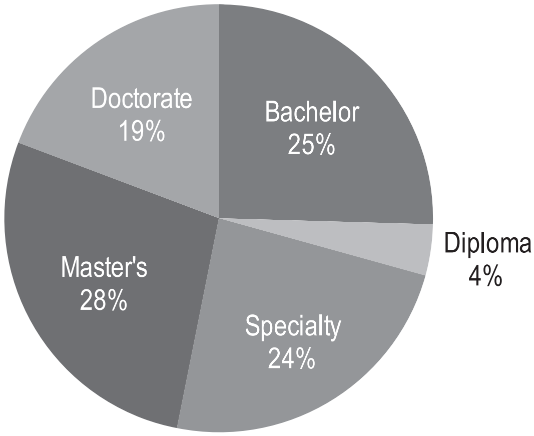
Besides conducting research, CONACYT PRCs also offer teaching programmes, with an average of around 7 000 students enrolled in any one year over the past decade (Figure 2.21). A large proportion of these are registered at the postgraduate level (Figure 2.22). In 2006, 80 programmes at the master's and PhD levels were offered, the vast majority outside the Mexico City area. These resulted in around 1 000 postgraduate theses in 2006.

Figure 2.21. Number of students enrolled at CONACYT PRCs, 1998-2007



Source: CONACYT.

Figure 2.22. Enrolled students at the CONACYT PRCs, 2006



Source: CONACYT.

Despite the stated sectoral mission of PRCs and their regional distribution, too few efforts and resources are devoted to technology diffusion and the provision of technological services to the vast majority of firms that do not have access to technology information and financing. This is a common challenge for PRCs across the world. In many smaller firms, especially in the low- to medium-technology sectors that constitute the bulk of the Mexican economy, innovation tends to be a temporary activity because of limited resources; in larger firms innovation is frequently a continuous activity. Their innovation also tends to be incremental rather than radical and therefore does not demand the sophisticated research produced in public labs and HEIs. But even where enterprises, and more specifically SMEs, need the services of public research, communication barriers frequently affect or prevent collaboration. These may arise from lack of motivation at the PRCs, differences in competence levels between partners, or the fact that the cost in terms of time and money for getting acquainted with a large number of small partners and their problems is comparatively higher than with a larger partner.

For the commercialisation of research findings, legal modifications introduced in 2006 empower PRCs' governing bodies to establish the conditions of use and to appropriate the results generated by their researchers. They can set confidentiality conditions when profitable knowledge is generated in the framework of joint PRC-industry projects or in technology-based firms created by PRCs. It is expected that these reforms will improve PRCs' performance in terms of industrial property rights granted. Until now, only the Mexican Institute of Petroleum (IMP) and the Electrical Research Institute (IIE) have been proactive in applying for and obtaining patents. In fact, IMP stands out as one of the most important patentees in Mexico, with 610 national and 60 international patents and 90 trademarks. By contrast, the CONACYT PRCs submitted just 27 patent applications among them in 2006.

In addition to these changes in intellectual property regimes, the degree of autonomy of CONACYT PRCs – concerning the orientation and organisation of their activities – has increased in recent years. In accordance with the Law of S&T and its 2006 reforms, they can now co-operate with public and private firms, realise joint projects with them, form technology-based firms and obtain funds for scientific research and technological development by means of self-generated resources and donations. All decisions relating to budget, technical, operative and administrative matters are the responsibility of their governing bodies. Similar changes have occurred in many other non-CONACYT PRCs (Box 2.6).

Box 2.6. Reforms at INIFAP

The *Instituto de Investigaciones Forestales, Agrícolas y Pecuarias* (INIFAP) was established in 1985 through the merger of three formerly independent research institutes, each of which had been founded some 25 years earlier. It employs more than 1 000 researchers working on the improvement and generation of new crops and plant varieties and on improving livestock. It consists of 6 national disciplinary research centres, 8 regional centres and 81 experimental field stations. Nowadays, INIFAP operates under the Secretary for Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA). Its goals are to contribute to sustainable rural development by improving competitiveness and preserving the Mexican natural resources base and to do so by bringing together efforts and funding from public and private organisations linked to the rural sector. Some important features of the activities carried out by the Institute over the period 2004-07 include:

- Modification of INIFAP's legal status which increased its technical, financial and operational autonomy to perform its activities. These can therefore be better co-ordinated with national development goals as stated in the 2007-12 Plan Nacional de Desarrollo (PND). Autonomous evaluations carried out by independent third parties should assess INIFAP's performance according to the institute's strategic plan, currently for the period 2006-11. Research and other activities are already aligned or in process of alignment with the strategic plan.
- The first external evaluation (2003) documented the pertinence and quality of INIFAP's research activities for the country as a whole. Yet, important gaps remain at the regional level. Some improvements would have been obtained by adopting funding mechanisms based on competitive grants. Recommendations also led INIFAP to develop its first formal policy for technological innovation and the application, since 2002, of the first guidelines for the provision of incentives to researchers based on productivity. In addition, there are new guidelines for the conduct of research and for the administrative operation of the institute.
- Regionalisation efforts are also evident. Besides the movement of 12% of its personnel from the central to regional units, the share of mid-rank managerial positions in the latter grew from 51% in 2004 to 63% in 2005. Regional consolidation of infrastructure and research activities also brought down the number of experimental fields from 82 in 2004 to the current 36 fields and 3 business sites.
- Aligning research to the renewed goals of the institute has been possible by placing current and prospective demands of regional "end users" at the forefront of the "innovation chain". Up until 2007, 15 workshops had been carried out according to a three-step process that looked at: *i)* available products resulting from previous research; *ii)* current and future research projects which had translated into specific projects as of 2006; and *iii)* the conformity of regional innovation networks with some strategic plans defining specific deliverables. A catalogue of 32 such networks has already been prepared.
- Definition in 2005 of the "Grand Vision" project to respond to future needs of the economy and society at large. These include: water, genetic resources, biotechnology, climate change and alternative energy sources. Funding for research on these topics comes from INIFAP's own funds.
- Regarding IPRs, actions include the registration of the trademark "INIFAP" to support commercialisation of products generated by the institute.
- INIFAP signed 96 agreements with national and 14 with foreign organisations, including universities, firms and governments in relation to S&T in the agriculture sector.

Despite these promising reforms, some significant challenges remain. For example, renewal of the research body is increasingly urgent. The annual rate of researcher turnover since the 1980s has been less than 1%. Moreover, the average age of researcher staff is 50 years, while the mean for the period of service is 25 years. By 2020, a significant share of the personnel will be retiring owing to age or number of years in service. Yet, attempts to open new positions have so far been less successful than hoped.

Although not yet sufficiently developed to have a significant impact on the intensity of science-industry relationships, these changes are a positive trend that could gather momentum if remaining constraints to PRCs' autonomy are reduced. These concern, in particular, regulatory frameworks that submit equipment investment and personnel management to centralised control, which tends to adversely affect contractual arrangements with private enterprises and the management of intellectual property rights (IPR) regimes. This is discussed further in Chapter 3.

2.3. Higher education institutes

Mexico's higher education system consists of universities, technological institutes, state educational institutions, and normal schools (for the training of teachers). The system's foundations were put in place and consolidated during the era of import substitution. The most important public and private HEIs, such as the National University of Mexico (UNAM), the National Polytechnic Institute (IPN), the Technological Institute of Higher Studies of Monterrey (ITESM), the Metropolitan Autonomous University (UAM), as well as various state universities were established between 1930 and 1980. The number of HEIs grew from 26 to 84 from 1950 to 1980. However, it was during the latter part of the 20th century that Mexico experienced an unprecedented explosion in higher education in terms of the number and variety of institutions, students, faculty and research. By 2005, Mexico had 2 807 HEIs, of which 40% are public and 60% private, located all over the country (Table 2.11). While fewer in number, public HEIs attracted nearly 68% of undergraduate and 58% of postgraduate students in 2006. The proportion of students attending private HEIs is on the rise, however, increasing from 18.5% of the undergraduate total in 1990 to 32% in 2006.

Table 2.11. Typology of Mexican higher education institutions

Public		Private	
Universities	355	Universities	550
Institutes	362	Institutes	445
Centres	118	Centres	424
Normal schools	247	Schools	223
College	21	College	60
Total public	1 103	Total private	1 702
Total: 2 807			

Source: ANUIES.

It is important to understand the contributions that HEIs make to innovation. All too often, policy attention is overly focused upon the production of codified knowledge through research and its subsequent diffusion and exploitation through various "third stream" activities and industry-academic linkages. However, the innovation studies literature makes clear that the most significant contribution of HEIs to innovation often lies in the creation of capabilities through teaching and research training activities. Accordingly, this section begins with consideration of the role of Mexican HEIs in providing tertiary education before turning to their research activities. It then reviews governance arrangements, with particular reference to the autonomous status of HEIs and the quality assurance mechanisms in place.

2.3.1. Tertiary education

Higher education is conceived as one of the principal ways by which Mexico is to be modernised. It is viewed as a national enterprise to create human capital, greater social integration and greater participation by youth in education in order to stimulate and ensure long-term economic growth. Accordingly, over the last half century or so, participation rates in higher education have increased from 1% to one-quarter of the 19-23 age group (Table 2.12). In 2006, approximately 380 000 students gained a tertiary education qualification: 87.3% a first degree, 3.1% a specialty, 9.1% a master's and 0.5% a PhD. In Mexico, 61% of those who enter undergraduate degree programmes go on to successfully complete their studies. This is below the OECD average of 69% (OECD, 2008e), partly on account of poorer students' difficulties for supporting themselves financially during their studies.

Table 2.12. Flows of graduates by degree level, 1997-2007

Year	Undergraduates	Postgraduates		
		Specialty	Master	Doctorate
1997	183 417	5 466	14 509	893
1998	184 258	7 907	15 958	714
1999	200 419	9 155	18 877	911
2000	209 795	9 266	19 373	1 035
2001	227 095	10 314	23 632	1 085
2002	249 085	10 307	26 253	1 446
2003	268 155	10 099	26 840	1 390
2004	287 676	10 515	29 395	1 657
2005	309 157	11 302	32 044	1 783
2006	331 807	11 718	34 393	1 910
2007	N/A	12 890	37 832	2 101

Note: Data for 2006 and 2007 are estimates.
Source: ANUIES.

Institutions derive their revenues from four major sources: federal subsidies, state subsidies, student tuition fees and external sources of income (*e.g.* research contracts, provision of services, industry training). No systematic data are available regarding the relative importance of each of these sources. Public subsidies are not allocated to tertiary education institutions on the basis of a widely agreed funding framework covering the entire system. Federal public universities are publicly funded by the federal government only. Autonomous state public universities receive mixed public funding from both the federal and the state governments; their relative contributions are the subject of an agreement between them and the individual institution.

The federal subsidy has three main components: *i)* an ordinary subsidy; *ii)* an extraordinary subsidy, which can be classified as targeted funding; and *iii)* a subsidy linked to the annual expansion and diversification of the educational supply base. In turn, the state subsidy has two components: an ordinary subsidy and a subsidy related to the expansion of the educational supply base. By far the most significant of these various funding components is the ordinary subsidy, which can be considered a "block grant" that covers current expenditure related to the regular activities of institutions. It is formally based on the size of an institution's academic body but more often than not reflects historical trends or the lobbying power of the institution. About 90% of the total public subsidy for tertiary institutions is concentrated in the ordinary subsidy which also includes the basic funding for research. No quality-related indicator is used in determining the ordinary subsidy, which means there are few levers to provide incentives for institutions to strengthen teaching (and research) quality (OECD, 2006a).

During 2000-05, Mexico saw modest increases of expenditure per student at the tertiary level. This coincided with a 20% increase in enrolments, although tertiary education enrolment rates remain among the lowest in the OECD area (31% in 2006 compared to the OECD average of 56%). Spending per student is, at USD 6 402 in 2005, slightly more than half of spending per student at the OECD average level (USD 11 512). Although the figures are low in absolute terms, they represent 1.3% of GDP, a figure higher than in many OECD countries and comparable to the OECD average of 1.4%. Public spending on tertiary education in Mexico rose by 19% between 2000 and 2005 (below the OECD average of 26%). However, private spending increased by 106%, with the result that the private share of funding in tertiary education in Mexico increased from 21% to 31% (OECD, 2008e).

Mexico's financing of tertiary education faces important challenges. A first matter for concern is whether the current heavy reliance on public money is sustainable. Even though the principle of cost-sharing between the government and individual beneficiaries of tertiary education has been introduced, the extent to which (more affluent) students contribute to the costs of their tertiary education seems fairly limited. At the same time, Mexico has the largest gap in the OECD area between per-student expenditure for tertiary education and for lower levels of education. There is therefore growing pressure to shift some resources from tertiary education to school education.

2.3.2. Research activities of HEIs

Almost one-half of research activity in the HEI sector is concentrated in just four institutions, namely the National Autonomous University of Mexico, the Centre for Research and Advanced Studies (CINVESTAV), the Metropolitan Autonomous University and the National Polytechnic Institute. Outside of Mexico City, the University of Guadalajara (UdG) and the Autonomous University of Puebla (BUAP) are two of the largest state universities conducting research. The most prominent private HEI in this respect is the Monterrey Technological Institute for Higher Education (ITESM). Each of these institutions is briefly described in Box 2.7 and the geographical distribution of HEIs offering PhD programmes is shown in Figure 2.23.

Box 2.7. Major research HEIs in Mexico

UNAM: Formally established in 1910, UNAM is the oldest and largest HEI in Mexico. UNAM's research centres and research institutes are distributed across the country, though most are concentrated in Mexico City. In 2007 these centres and institutes employed 2 337 researchers and 1 693 technicians. Scientific production consisted of 3 084 articles, 1 283 reports in internal yearbooks, 397 books and 948 book chapters. UNAM is the most important centre for training human resources at the postgraduate level. In the 2006-07 academic year, almost 21 000 were enrolled in different programmes and disciplines, with 17% of these accounted for by doctoral programmes.

IPN: Founded in 1936, IPN is strongly oriented to technological research, although excellence in some scientific research areas is also well recognised. Research at IPN is mostly concentrated in its 19 research centres located across the country. In 2007, 1 579 researchers conducted 436 projects in all research centres. Between 1997 and 2006, its researchers published 5 536 articles in international journals. IPN offers 90 postgraduate programmes. In the 2006-07 academic year, a total of 5 199 students were enrolled in postgraduate programmes, with a little over 20% of these accounted for by PhD programmes.

UAM: Founded in 1974, UAM is the third largest HEI in Mexico, with practically all of its academic activities carried out in four campuses located in Mexico City. In 2006, 2 193 full-time researchers worked in around 140 research areas. During 1997-2006, UAM researchers published 5 708 articles in international journals. In the 2006-07 academic year, approximately 45 000 students were enrolled at undergraduate level, with a further 1 857 students enrolled in 21 postgraduate programmes.

CINVESTAV: Founded in 1961, CINVESTAV is organised into 28 academic departments located in 9 centres, two of which are in Mexico City. In 2005, its 549 researchers produced 904 scientific articles in international journals. CINVESTAV is the leading national academic institution in patenting and in transferring technologies to the private sector. It holds 105 national and 52 international patents, and 30 technologies developed by CINVESTAV researchers have been transferred. CINVESTAV offers several postgraduate programmes at the Master and PhD level, with around 3 500 students enrolled in the 2005-06 academic year.

BUAP: Formally founded in 1937, BUAP is one of the most important universities in terms of research outside Mexico City. In 2005, it had 534 researchers. During 1997-2006 a total of 2 680 scientific articles were published. The BUAP offers 58 postgraduate programmes, with around 15% of the cohort enrolled at PhD level.

UdG: Founded in 1925, UdG is the country's fourth largest HEI, located in the Guadalajara Valley. In 2006, nearly 3 000 academics (not all of whom are active in research, and around 500 registered in the SNI) worked at UdG. Its researchers published around 2 000 scientific papers in international journals over the ten years to 2006. Over the last decade, UdG has developed important linkages with the electronics sector, a major employer in the region. UdG offers a total of 147 postgraduate programmes, with 3 900 enrolled in 2006-07, around 8% of whom registered in PhD programmes.

ITESM: Founded in 1943 by a prominent entrepreneur in Monterrey, ITESM is the leading private HEI in Mexico and has 33 campuses across 21 states. In 2007, 2 787 full-time personnel were devoted to teaching and research activities, 235 of whom were SNI members. Around 11 000 students were registered in 53 Master and 9 PhD programmes in 2007.

Figure 2.23. Higher education institutions hosting doctoral programmes

Number of HEIs by state

Source: CONACYT.

In 2005, HEIs accounted for almost 29% of Mexico's total research effort and were the second largest employers of researchers (around 16 700 FTE). Higher education expenditures on R&D (HERD) increased by around 75% between 1999 and 2005 (from USD 923 million to USD 1 623 million in current PPP). As a percentage of GDP, however, HERD increased only marginally during that time from 0.10% to 0.13% (Table 2.13). This placed Mexican HERD among the lowest in the OECD, comparable to that in countries where non-university public research organisations play a more prominent role in the research system (Figure 2.24).

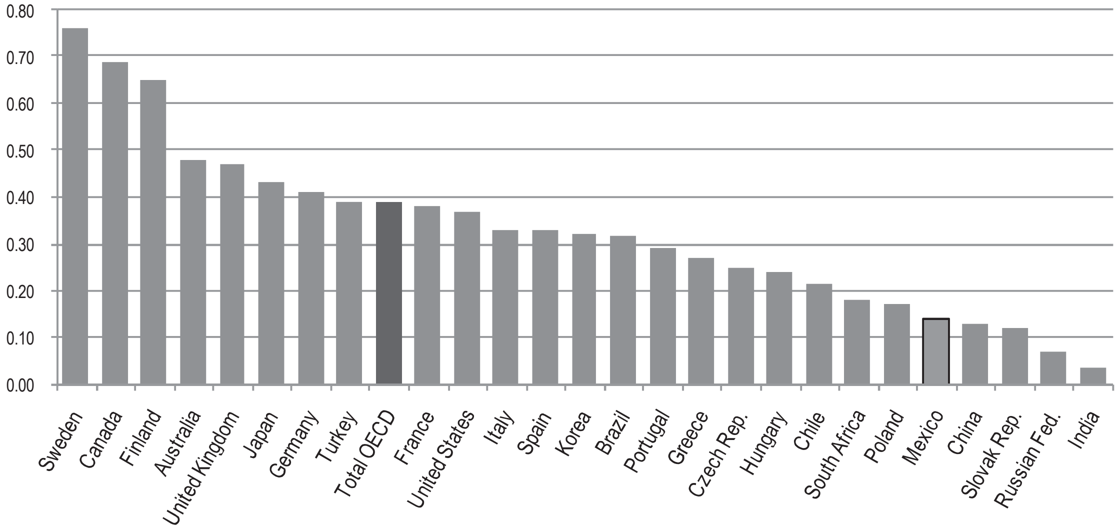
Table 2.13. HERD indicators for Mexico, 1999-2005

	1999	2001	2003	2004	2005
HERD (% of GDP)	0.10	0.11	0.15	0.12	0.13
HERD (million current PPP USD)	923	1 104	1 664	1 442	1 623
HE researchers (FTE)	10 648[1]	n.a.	17 135	16 043[1]	16 691[1]

1. National estimate.

Source: OECD Main Science and Technology Indicators.

Figure 2.24. HERD as a percentage of GDP in selected countries, 2006[1]

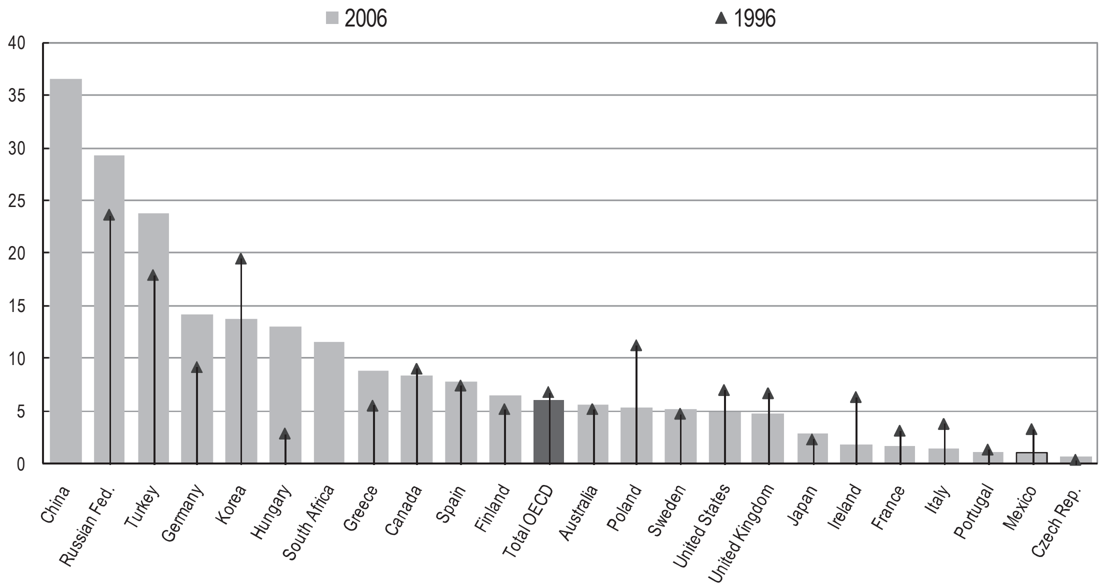


1. Or nearest available year.

Source: OECD Main Science and Technology Indicators.

The level of HERD financed by industry stood at around 1% in 2005, a figure well below the OECD average (Figure 2.25). Moreover, as in the case of industrial funding of GOVERD, the percentage of HERD financed by industry has declined in recent years (Figure 2.26). This reflects in part increased government spending on HERD.

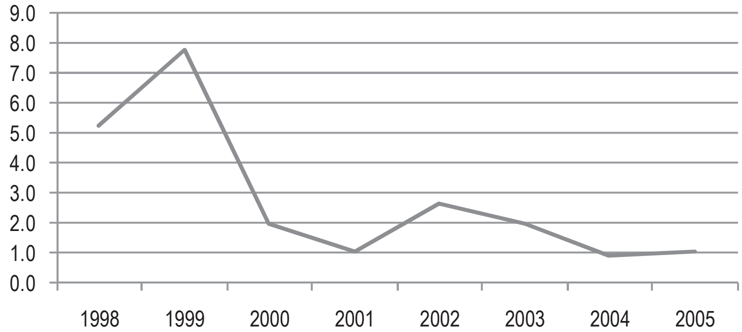
Figure 2.25. Percentage of HERD financed by industry in selected countries, 1996 and 2006[1]



1. Or nearest available year.

Source: OECD Main Science and Technology Indicators.

Figure 2.26. Percentage of Mexican HERD financed by industry, 1998-2005



Source: OECD Main Science and Technology Indicators.

2.3.3. Governance – autonomy and quality assurance

Tertiary education governance, co-ordination and regulation take place at the federal and state levels. At the federal level, policy is established by the Ministry of Public Education (*Secretaría de Educación Pública* – SEP), specifically through the Higher Education Under-secretariat (*Subsecretaría de Educación Superior* – SES). At the state level, co-ordination of tertiary education is the responsibility of the respective state ministries of public education through different administrative units (*e.g.* higher education departments or general directions of higher education).

As in other national tertiary education systems, Mexico must continually review the appropriate balance between governmental steering and institutional autonomy in pursuit of better alignment between the system's operation and national socio-economic development goals. While universities' autonomy is guaranteed by the Mexican Constitution, their governance is quite diverse. For example, public federal and some state universities enjoy autonomy and self-government according to their statutes, while a second group of public institutions –non-autonomous state universities, technological, polytechnic and intercultural universities, and state and federal technological institutes – do not have autonomous status. They report directly to the federal and/or state government (through SEP and/or states' Department of Education) but in practice they do have significant autonomy (OECD, 2006a). Private-sector institutions, while theoretically fully autonomous, are dependent upon federal or state authorities to award them university status and to approve their degree programmes.

This autonomy necessitates the development of effective systems of institutional monitoring and quality assurance. A number of complementary approaches are used for teaching programme quality assurance. Some are wholly internal to institutions, while others are external, involving, for example, accreditation by non-governmental organisations or programme approval by SEP. At postgraduate level, programme-wide assessments were introduced by SEP and CONACYT in 2002 in the framework of the National Registry of Graduate Programmes (PNP). Programmes that receive a positive assessment are listed in the registry under two categories, namely "international quality" or "high quality". By mid-2006, 660 programmes in 48 public and private institutions were listed in the PNP (OECD, 2006a). Furthermore, various instruments have been put in place to enhance the quality of research. The most prominent of these is the National System of Researchers (SNI) where individual researchers can apply for the distinction of "recognised researcher". This is awarded by CONACYT on the basis of a peer review of publications, generally every three years. In addition, the growing amount of research funds distributed on a competitive project basis (see Chapter 3) has allowed for the introduction of research quality measures as part of the criteria for project selection.

2.3.4. Academic workforce

In the 2004-05 academic year, close to 250 000 academic staff were employed in Mexican HEIs, 62% in public institutions and 38% in private ones. The staff increased by 85% over the previous decade, slightly more than the 79% increase in student numbers. Despite this increase, the workforce faces several challenges. To begin with, the base salary of academic staff in Mexico is very low and considered insufficient to sustain a middle-class lifestyle. It is perceived as being uncompetitive *vis-à-vis* salaries offered in the private sector, especially at the early career stage. Furthermore, part-time academic staff, who are a majority in Mexican institutions, receive only modest payment for each course they teach. Remuneration typically comprises three components: the base salary, a merit-based component (which requires a voluntary application by the academic), and a supplement for members of the SNI. In 2005, only 17% of Mexican full-time academics had achieved SNI membership. For those who are SNI members, the base salary may represent just one-third of their overall remuneration. For others, the merit-based supplement will represent a significant proportion of their remuneration (OECD, 2006a).

A further problem is that pension benefits are generally linked only to the base salary, which provides little incentive for academics to retire given the considerable fall in income that this entails. This is leading to an ageing of the academic workforce in some institutions, particularly in those, such as federal universities, where few new posts are created. Matters are not helped by very limited mobility of academic staff in Mexico. Typically, an individual starts his/her career in a given institution and remains there throughout his/her working life. This is encouraged by career structures that are defined mostly at the institutional, rather than at the national, level (OECD, 2006a).

2.4. Human resources

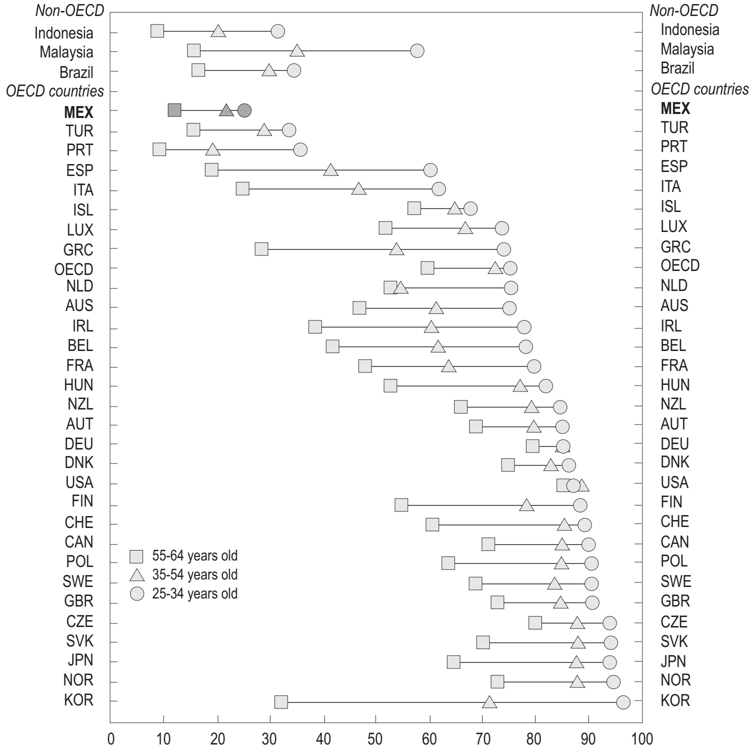
Human resources constitute perhaps the main pillar of knowledge-based economies and as such are a major concern of innovation policy. This section begins with a discussion of the performance and productivity of the secondary and tertiary education sectors, followed by discussion of supply and demand issues around the highly skilled. It finishes with a brief review of lifelong learning provision.

2.4.1. Education system: spending and performance

Mexico still fares poorly by OECD standards in the quantitative and qualitative formation of human capital at all stages of education, from primary schooling to lifelong learning. This relatively poor performance is reflected in particular in the low level of educational attainment of the working age population (Figure 2.27).

Figure 2.27. Educational attainment of the working-age population, 2003[1]

Population with at least an upper-secondary qualification



1. Percent of each group. 2002 for the Czech Republic, Iceland, Italy and Netherlands.

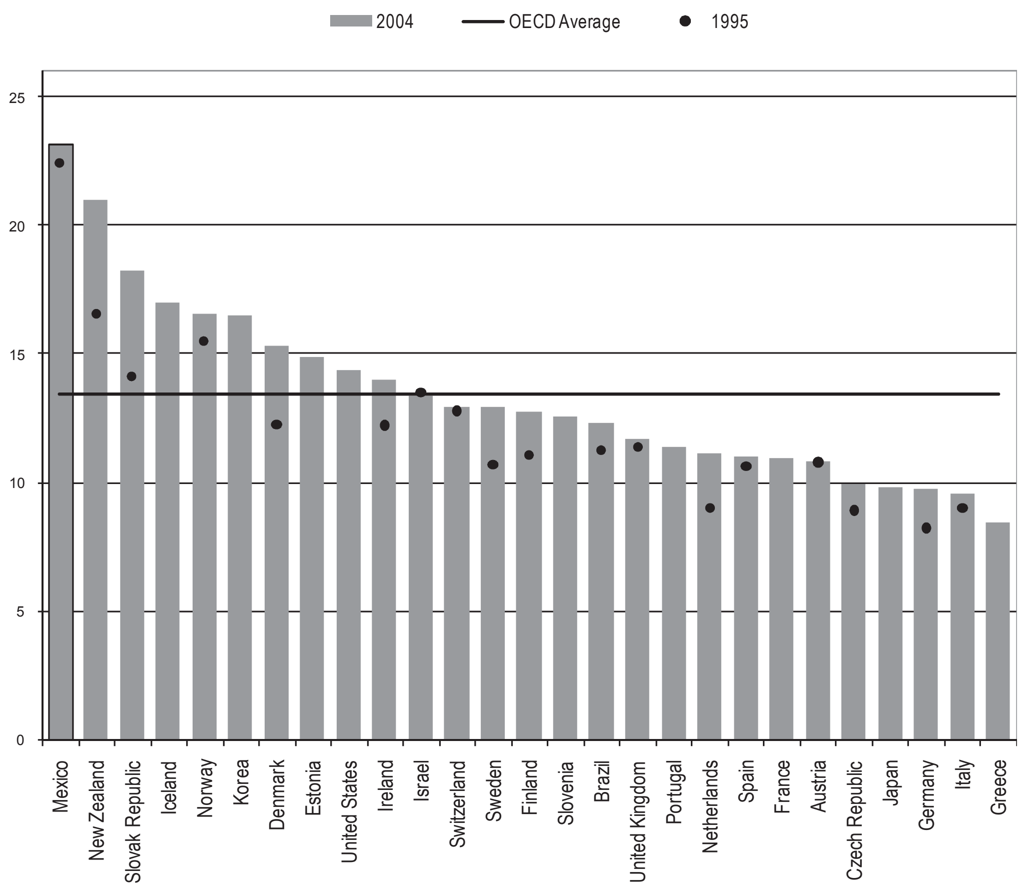
Table 2.14. Main elements of the Mexican education system

Type of education	Level	School-based	Non-school-based
Basic education	Initial education	Initial education	
	Pre-school	General	
		Community	
		Indigenous	
	Primary	General	Primary for adults
		Community	
		Indigenous	
	Lower secondary	General	Lower secondary for adults
		Community	
		Indigenous	
	Vocational training	Technical training	Vocational training
Upper secondary education	Technical professional	Technical professional	Open and distance learning
	Baccalaureate	General	
		Technical	
Higher education	Higher technical	Higher technical	Open and distance learning
	Bachelor's degree	Teacher training	
		University degree	
		Technical degree	
	Postgraduate education	Specialist	
		Master's degree	
		PhD degree	

Source: SEP.

Mexico has one of the largest and most complex education systems in Latin America, composed of federal and state education institutions, decentralised organisations, private education institutions and a number of public universities. As Table 2.14 shows, the system provides education at three levels: basic education, upper-secondary education and higher education. Throughout most of the 20th century, only primary education was compulsory, but in 1993, lower secondary education was made mandatory and in 2002, education at pre-school level. Over the last decade or so, the share of public spending on education has been the highest among OECD countries, standing at 23% in 2004, a figure almost twice the OECD average (Figure 2.28). This is mostly due to low tax receipts, which permit the Mexican government to focus on the provision of core services such as education. Educational spending as a percentage of GDP increased from 5.6% in 1995 to 6.4% in 2004, and is above the OECD average of 5.8% (Table 2.15).

Figure 2.28. Expenditure on education as a percentage of total public expenditure, 1995 and 2004



Note: Direct public expenditure on educational institutions plus public subsidies to households (which include subsidies for living costs), and other private entities as a percentage of total public expenditure, for all levels of education combined and by year. Countries are ranked in descending order of total public expenditure on education at all levels of education as a percentage of total public expenditure in 2004.

Source: OECD (2007), *Education at a Glance*, OECD, Paris.

Table 2.15. Expenditure on educational institutions as a percentage of GDP, 1995, 2000 and 2004

By levels of education, from public and private sources

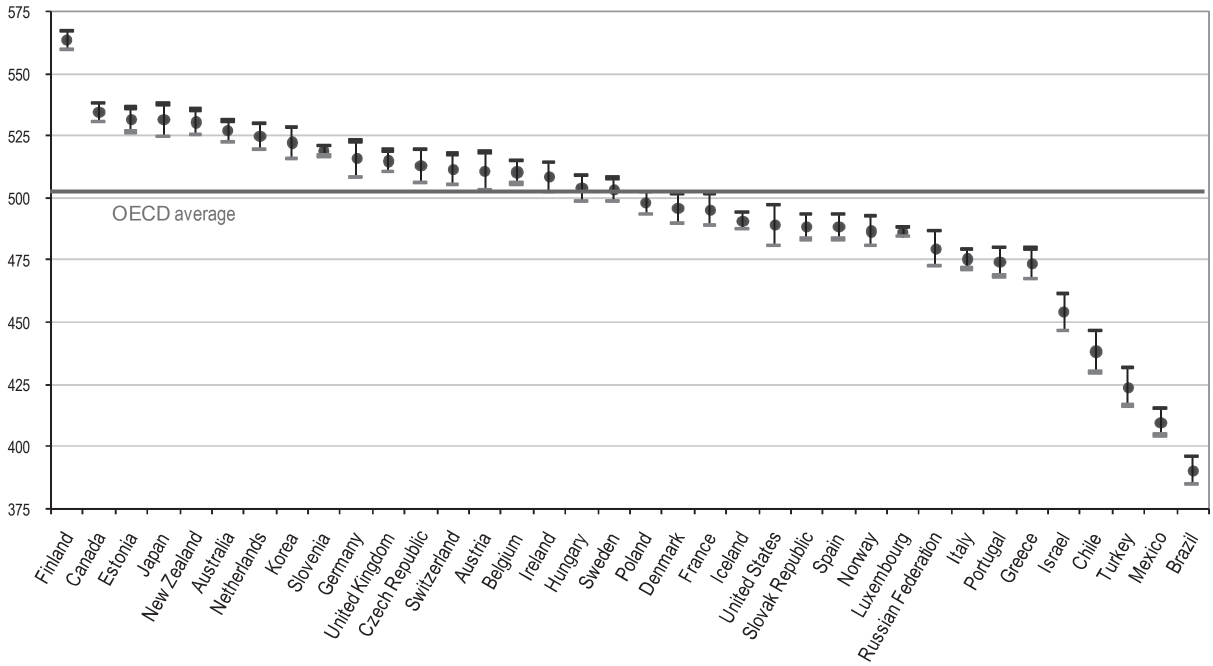
	2004			2000			1995		
	Primary, secondary and post-secondary non-tertiary education	Tertiary education	Total all levels of education	Primary, secondary and post-secondary non-tertiary education	Tertiary education	Total all levels of education	Primary, secondary and post-secondary non-tertiary education	Tertiary education	Total all levels of education
France	4.1	1.3	**6.1**	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Germany	3.5	1.1	**5.2**	m	m	n.a.	3.7	1.1	**5.4**
Greece	2.2	1.1	**3.4**	2.3	0.7	**3.1**	1.8	0.5	**2.3**
Hungary	3.5	1.1	**5.6**	2.9	1.1	**4.9**	3.5	1.0	**5.3**
Italy	3.4	0.9	**4.9**	3.2	0.9	**4.8**	n.a.	0.7	n.a.
Japan	2.9	1.3	**4.8**	3.0	1.3	**4.8**	3.1	1.1	**4.7**
Korea	4.4	2.3	**7.2**	4.0	2.6	**7.1**	n.a.	n.a.	n.a.
Mexico	**4.3**	**1.3**	**6.4**	**3.8**	**1.1**	**5.5**	**4.0**	**1.1**	**5.6**
Poland	3.8	1.5	**6.0**	3.9	1.1	**5.6**	n.a.	n.a.	n.a.
Portugal	3.8	1.0	**5.4**	3.9	1.0	**5.4**	3.6	0.9	**5.0**
Spain	3.0	1.2	**4.7**	3.2	1.1	**4.8**	3.8	1.0	**5.3**
Turkey	3.1	1.0	**4.1**	2.4	1.0	**3.4**	1.7	0.7	**2.4**
United Kingdom	4.4	1.1	**5.9**	3.6	1.0	**5.0**	3.9	1.2	**5.5**
United States	4.1	2.9	**7.4**	3.9	2.7	**7.0**	3.9	2.4	**6.6**
OECD average	**3.8**	**1.4**	**5.8**	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Brazil[1]	2.9	0.7	**3.9**	2.8	0.7	**3.8**	2.5	0.7	**3.6**
Chile[2]	3.8	2.0	**6.4**	4.3	2.2	**6.9**	3.1	1.7	**5.1**

1. Expenditure from public sources only.
2. Year of reference 2005.

Source: OECD (2007), *Education at a Glance*, OECD, Paris.

Despite these reforms and the large proportion of public spending on education, Mexico still has one of the lowest levels of years of schooling in the OECD area. One reason is that the absolute levels spent on education are low compared to other OECD countries. This has implications for educational attainments, as indicated by Mexico's relatively weak performance in the OECD's Programme for International Student Assessment (PISA) exercise. PISA examines, through tests and surveys of 15-year-olds, how well individual national education systems are doing in equipping their young people with essential skills. The latest round of PISA, carried out in 2006, set out to measure the science performance of 15-year-olds. Figure 2.29 shows Mexican performance to be the lowest in the OECD area.

Figure 2.29. Distribution of student performance on the PISA science scale, 2006



Note: Figure shows the mean score on the PISA science scale, with 95% confidence interval around the mean score.

Source: OECD (2008), *Education at a Glance,* OECD, Paris.

Unlike many traditional assessments of student performance in science, PISA is not limited to measuring students' mastery of specific science content. Instead, it measures the capacity of students to identify scientific issues, explain phenomena scientifically and use scientific evidence as they encounter, interpret, solve and make decisions in life situations involving science and technology. This is important, since if students learn merely to memorise and reproduce scientific knowledge and skills, they risk being prepared mainly for jobs that are disappearing from labour markets in many countries. For today's global economy, students need to be able to solve problems for which there are no clear rule-based solutions and also to communicate complex scientific ideas clearly and persuasively (OECD, 2007h). Mexican students performed relatively better on science questions for which they were asked to identify scientific issues. They found it relatively easier to figure out the key features of a scientific investigation. But they struggled to use scientific evidence and had difficulties analysing data and experiments.

PISA also divides student performance scores into six proficiency levels based on the difficulty of questions and the kinds of science competencies students have. While basic competencies are generally considered important for the absorption of new technology, high-level competencies are critical for the creation of new technology and innovation. For countries near the technology frontier, this implies that the share of highly educated workers in the labour force is an important determinant of economic growth and social development. There is also mounting evidence that individuals with high-level skills generate relatively large externalities in knowledge creation and utilisation, compared to an "average" individual (OECD, 2007h). On average across OECD countries, 9% of 15-year-olds reach levels 5 and 6, the top levels of the PISA 2006 science scale. In Mexico only 3% of students achieved these levels and very few reached the top level, *i.e.* demonstrated that they could consistently identify, explain and apply scientific knowledge in a variety of complex life situations. This is a very important finding because, even if PISA cannot establish the causal nature of the relationship, the proportion of students performing at levels 5 and 6 at age 15 appears to be a good predictor of a country's research intensity. It explains 70% of OECD cross-country variation in the share of researchers in total employment (OECD, 2007h).

At the same time, the percentage of students at very low proficiency levels is an important indicator of the extent to which young people are being prepared to participate fully in society and in the labour market. At level 2, students start to demonstrate the science competencies that will enable them to participate actively in life situations related to science and technology (OECD, 2007h). Almost 20% of 15-year-olds in the OECD did not reach this level, while the figure for Mexican students was closer to one-half; again, one of the weakest performances in the OECD area.

With a large share of public spending already committed to education, it is probably unrealistic to expect major budgetary increases in the sector in the absence of increased tax receipts or greater use of private co-payments. This means that existing resources will need to be used more effectively and more efficiently if Mexican PISA performance is to reach levels closer to the OECD average.

Table 2.16. Trends in entry rates at the tertiary level, 1995, 2000 and 2005

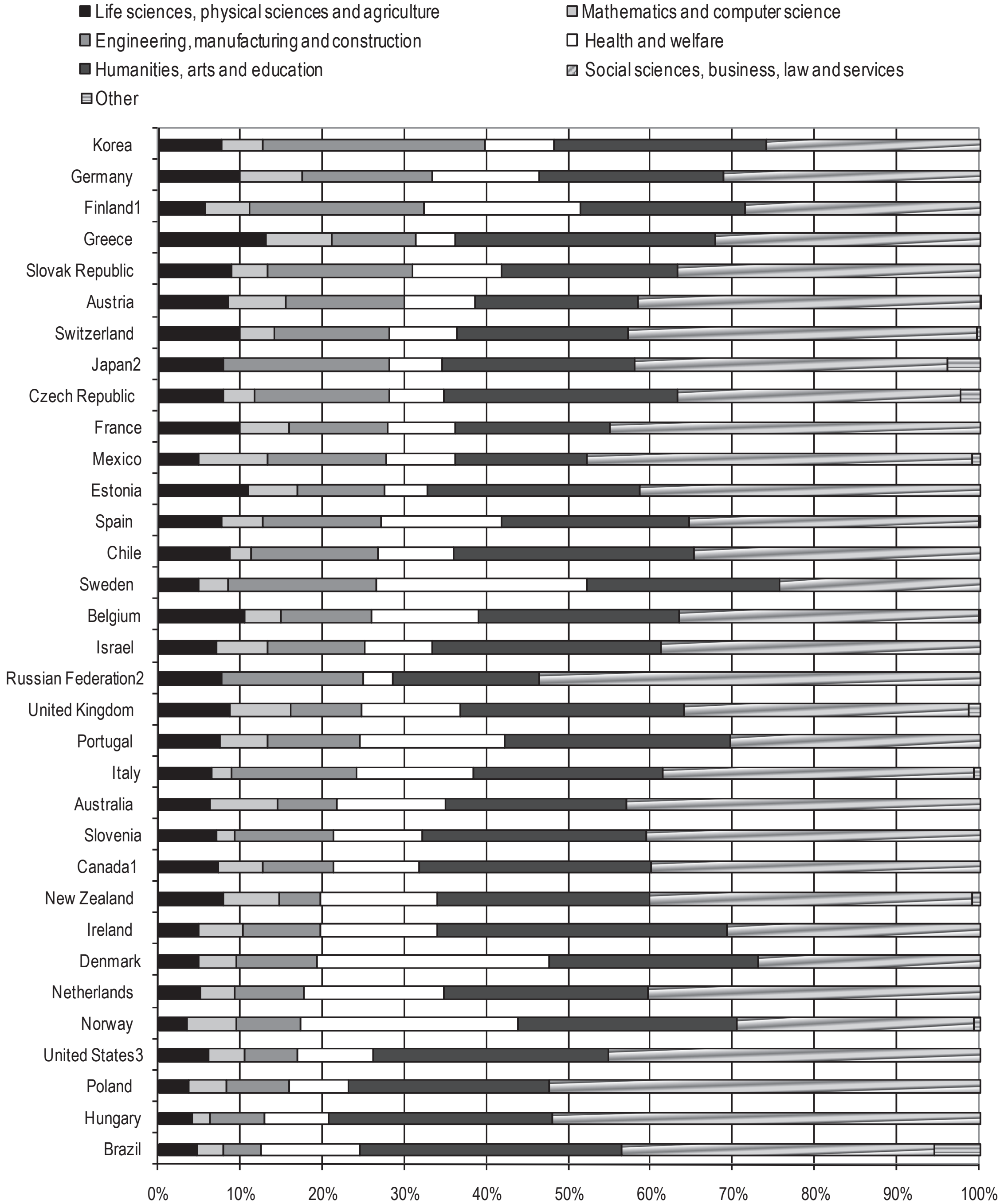
Sum of net entry rate for each year of age

	Tertiary 5A[1]			Tertiary 5B		
	1995	2000	2005	1995	2000	2005
Germany[2]	26	30	36	15	15	14
Greece	15	30	43	5	21	13
Hungary	n.a.	64	68	n.a.	1	11
Italy[2,3]	n.a.	39	56	n.a.	1	a
Japan[2,3]	30	35	41	31	29	30
Korea[2,3]	41	45	51	27	51	48
Mexico	n.a.	**27**	**30**	n.a.	**1**	**2**
Spain	n.a.	47	43	n.a.	15	22
Turkey	18	21	27	9	9	19
United Kingdom	n.a.	47	51	n.a.	29	28
United States	n.a.	43	64	n.a.	14	x(7)
OECD average	**37**	**47**	**54**	**18**	**15**	**15**
Chile[2,3]	n.a.	n.a.	48	n.a.	n.a.	n.a.

1. Entry rate for tertiary type A programmes included advanced research programmes for 1995, 2000, 2001, 2002, 2003.
2. Entry rate for tertiary type B programmes calculated as gross entry rate.
3. Entry rate for tertiary type A programmes calculated as gross entry rate.

Source: OECD (2007), *Education at a Glance*, OECD, Paris.

Figure 2.30. Tertiary graduates by field of education, 2005



Note: Includes only graduates with tertiary-type A and advanced research qualifications. Countries are ranked in descending order of the proportion of qualifications in life sciences, physical sciences and agriculture; mathematics and computer science; and engineering, manufacturing and construction.

1. Year of reference 2004.
2. Physical sciences, mathematics, statistics and computing are included in life sciences.
3. ISCED 5B programmes are included with ISCED 5A/6.

Source: OECD (2007), *Education at a Glance*, OECD, Paris.

2.4.2. Tertiary education attainment

Although it ranks among the lowest in the OECD area in university-level attainment, Mexico has seen impressive growth in tertiary qualifications over past generations, rising from 8% among 55-to-64-year-olds to 18% among 25-to-34-year-olds. Rates of current participation suggest that graduation rates will continue to increase. The increase in tertiary enrolment between 1995 and 2004, which will influence graduation rates, was, at 53%, considerably above the OECD average level of 41%. This trend is further underlined by Mexico's increasing entry rates to university. The proportion of Mexico's age cohort entering tertiary-type A programmes increased from 27% in 2000 to 30% in 2005 (Table 2.16). As Figure 2.30 shows, Mexico compares favourably to other OECD countries in the proportion of graduates gaining degrees in science and engineering subject areas.

In contrast to other OECD countries, Mexico has put much less emphasis on vocational tertiary education (tertiary-type B level programmes) during the last two decades, with an entry rate of just 2% for these programmes in 2005, well below the OECD average of 15% (Table 2.16). This is an area requiring urgent attention, since such programmes focus on practical and technical skills that have the potential to quickly enhance the performance of Mexican enterprises.

2.4.3. Skills supply and demand

The rate of growth in employment of Mexicans with tertiary education is well above the OECD average for both men and women (Table 2.17). Clearly, this is a positive development but it should be viewed in the context of initial low levels of graduate employment. A study by ANUIES (2003) shows that over 1990-2000, the labour market mostly absorbed tertiary education graduates – the net supply of graduates was 1.9 million while the aggregate demand for graduates stood at around 1.8 million. However, nearly half of all graduates appear not to have found employment in an area matching the competencies and skills acquired in tertiary education. Furthermore, about half of these were employed in less specialised areas in which most employed individuals did not hold a graduate degree. This suggests that the supply of jobs requiring tertiary level skills and competencies did not match the number of graduates with such skills (OECD, 2006a).

Table 2.17. Employment growth of tertiary-level graduates, 1998-2004

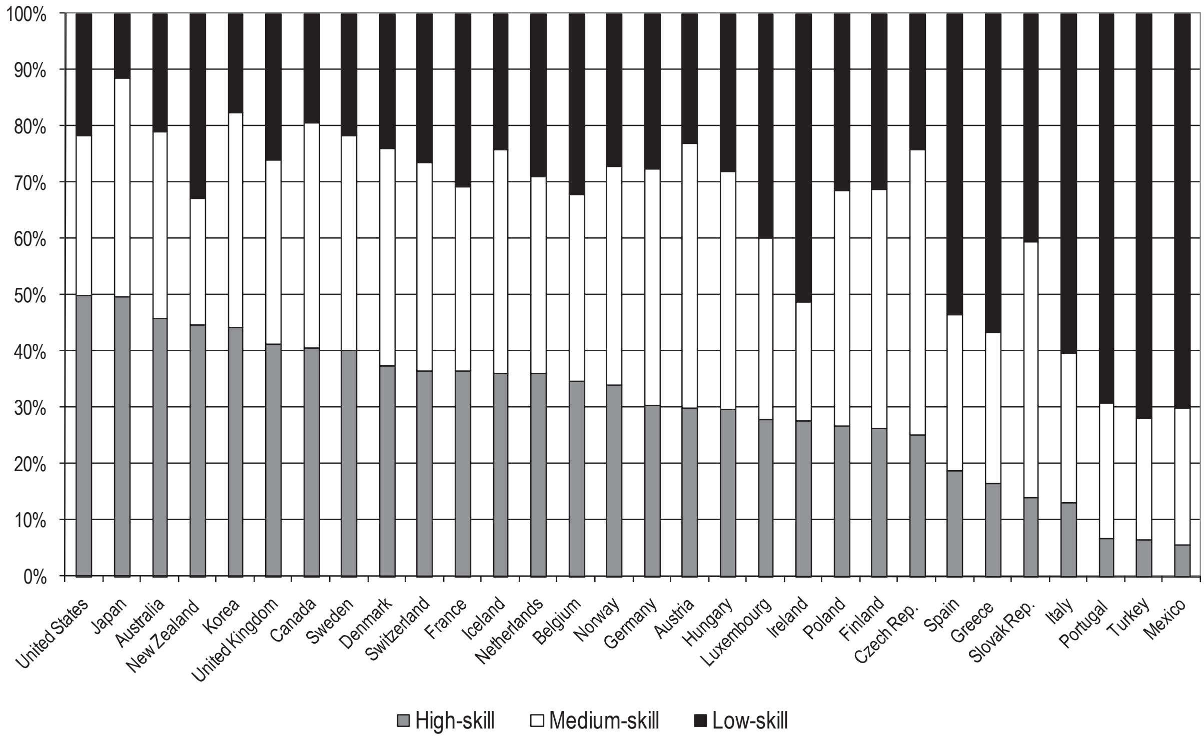
	Total employment growth	Tertiary-level employment growth	
		All-gender	Women
Mexico	1.8	5.2	7.4
OECD (1999-2004)	0.8	3.6	4.5

Source: OECD (2007), *OECD Science, Technology and Industry Scoreboard*, OECD, Paris.

Such "job mismatches" suggest that the skill mix supplied by the educational and training system is somewhat misaligned with the needs of the labour market. One interpretation of this situation is that recent increases in graduation rates have led to "over-education" of young Mexicans whose expectations of high-skill employment cannot be met in local labour markets. From this viewpoint, the growth in the supply of tertiary graduate skills has outpaced the demand by employers for such skills, thereby forcing graduates to accept jobs for which they are over-qualified or to seek better employment opportunities overseas.

The "brain drain" is not as strong in Mexico as in many other OECD countries, no doubt owing to the greater attention paid to the much larger proportions of unskilled Mexicans that seek to emigrate to the United States. Indeed, Mexico is the only OECD country for which general expatriation is greater than highly skilled expatriation as a percentage of the native-born (OECD, 2008f). As Figure 2.31 shows, Mexico has the lowest proportion of highly skilled expatriates in the OECD area. Nonetheless, given the very large overall number of Mexican emigrants, the actual number of highly skilled migrants is one of the highest in the OECD area. With a small inflow of similarly skilled labour, Mexico has the largest net outflow of skilled migrants in the OECD area (Figure 2.32).

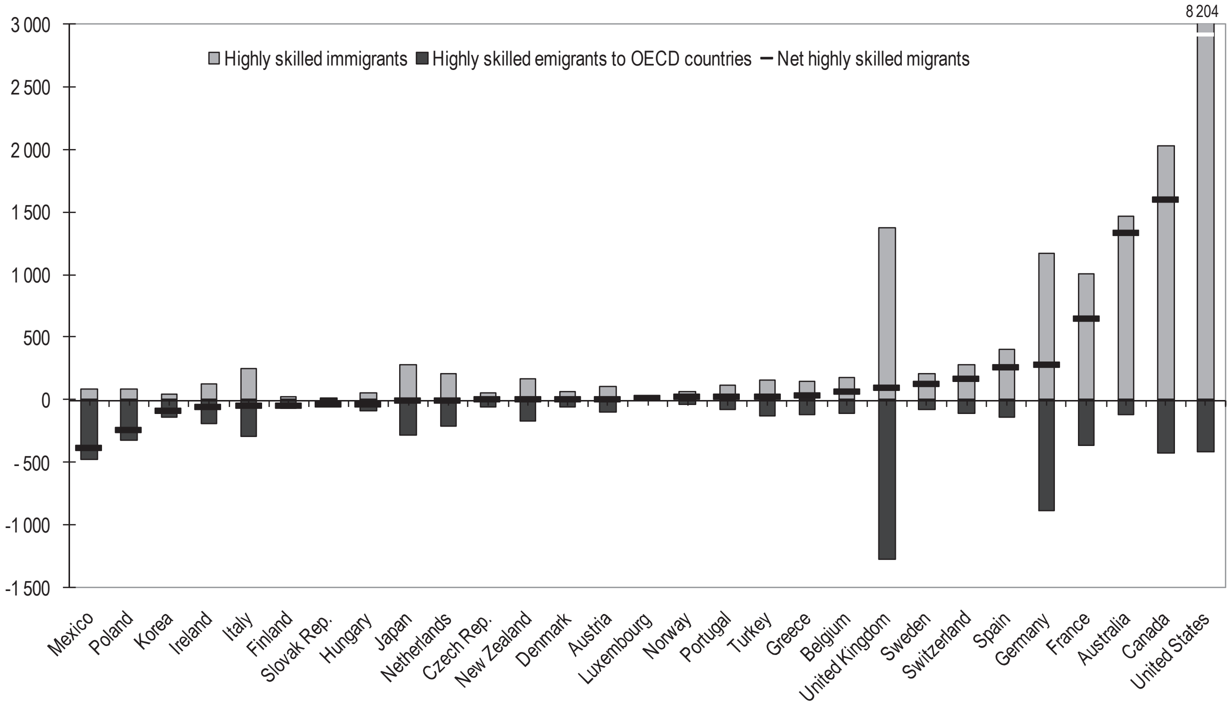
Figure 2.31. Distribution of expatriates by skill level and country of origin, 2001[1]



1. Or nearest available year.

Source: OECD (2008), *The Global Competition for Talent: Mobility of the Highly Skilled*, OECD, Paris.

Figure 2.32. Immigrant and emigrant population 15 years and over with a tertiary education, 2001[1]



1. Or nearest available year.

Source: OECD (2008), *The Global Competition for Talent: Mobility of the Highly Skilled*, OECD, Paris.

Another interpretation of the skills mismatch relates to the professional orientation available to university students and the ability of the university system to respond to changes in the labour market. For example, a recent review of Mexican tertiary education (OECD, 2006a) found that a few subject areas seem to concentrate too many graduates. As Figure 2.33 shows, around 45% of Mexican graduates studied “social sciences, business, law and services” in 2005, one of the highest proportions in the OECD. Yet, with only 30% of employed graduates having studied one of these topics, there would seem to be an oversupply of such tertiary programmes.

A number of initiatives have been put in place to try to improve the articulation of graduate supply and demand (Box 2.8), but there appear to be considerable outstanding challenges in linking the tertiary education system to the labour market. For example, there is no national forum where representatives of business and industry can contribute to the development of tertiary education policy. Furthermore, there is little tradition of active involvement of industry in the daily activities of institutions. The formal participation of employers and representatives of industry as external members of institutions’ governing bodies is a phenomenon largely limited to technological universities and some technological institutes and polytechnic universities. In other institutions, in particular autonomous institutions, their presence in governing bodies is scarce (OECD, 2006a).

Box 2.8. Articulation between the tertiary education system and the labour market

The articulation between the tertiary education system and the labour market takes place essentially at three levels.

First, several mechanisms seek to ensure that new educational offerings and the updating of existing offerings result from their relevance to the economy and the labour market. This was reflected in the 2001-06 strategy for education (PRONAE), which required the expansion and diversification of the educational supply in states to be associated with developmental plans designed by each state's COEPES. These reflect, among other things, an investigation of regional labour market needs. Individual institutions are also encouraged to improve their educational supply on the basis of graduate labour market outcomes, feedback from graduates and views of employers. It is notable that, over the ten years to 2004-05, out of the 290 public institutions created, 164 are part of the technology-oriented subsystems that lay particular emphasis on their links to the labour market (50 technological universities, 96 federal and state technological institutes and 18 polytechnic universities).

Second, partnerships between institutions and employers are encouraged. These include internship opportunities for students and teachers in industry, the contribution of professionals from industry to the delivery of programmes in institutions, the existence of offices in institutions to ensure liaison with employers and business organisations, and the participation of representatives of employers and businesses in advisory or governing bodies of institutions.

Third, detailed information about labour market outcomes is produced and made available to students, employers, institutions and policy makers. In 2005, the federal government launched the Mexican Observatory of the Labour Market (*Observatorio Laboral Mexicano*), an Internet platform (*www.observatoriolaboral.gob.mx*) with extensive information about trends and characteristics for a large number of occupations and professions. In addition, most institutions conduct surveys of graduates, receive governmental support to develop these and use the corresponding results to improve the organisation of their programmes.

Source: OECD (2006), *Thematic Review of Tertiary Education: Mexico*, OECD, Paris.

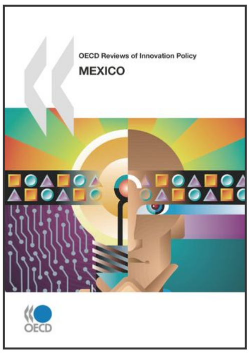
2.4.4. Lifelong learning

It is not enough to expand and improve secondary and tertiary education for coming generations. Such reforms must be accompanied by the development of an adult education and training sector that will not only provide continuous upgrading of the labour force, but will also respond to the long history of private and public under-investment in education. Furthermore, in an era in which new developments in science and technology are emerging constantly, investment in knowledge acquisition should be frequent and continuous. Qualification requirements and personal progress do not cease after attaining tertiary education. Constant education and training is thus considered an important step towards achieving a more effective educational system. Yet, Mexico has one of the lowest rates of participation of 25-to-64 year-olds in job-related training among OECD countries.

This is likely to limit both on the innovativeness of Mexican firms and their ability to adopt new technologies and business practices. The situation is complicated by the fact that the demand for skills is lower than that of several other economies because a large proportion of Mexican enterprises have adopted low-specification product strategies. This locks much of Mexican industry into a low-skill equilibrium. Consequently, there is a lack of training culture in the Mexican workplace, whereas in many OECD countries, employers tend to provide considerable opportunities for upgrading skills (OECD, 2004b). The dominant feature of the enterprise structure, *i.e.* the large number of SMEs, no doubt contributes to this. Matters are not helped by the tertiary education institutions, whose lifelong learning offerings remain underdeveloped. The opportunities for adults to undertake tertiary education after an experience in the labour market are also hindered by the absence of policy provisions to allow attendance on the basis of a person's assessed competencies instead of formal qualifications (OECD, 2006a).

Notes

1. It should be noted that a significant proportion of the 242% increase between 2003 and 2004 can be ascribed to measurement effects.
2. RENIECYT is the national register for firms and institutions wishing to qualify for various government schemes and incentives in support of S&T activities.
3. It should be noted that the CIS4 figures also include innovative firms with fewer than 50 employees. As such firms tend to be less innovative than their larger counterparts, it can be assumed that the proportion of innovative EC firms comparable in size to the Mexican sample (*i.e.* larger than 50 employees) would be even higher than the 40% cited here.
4. On the other hand, data for firms from the agricultural sector should be treated with caution owing to the extremely small sample of firms from this sector participating in the ESIDET survey.



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