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AREA I

Science and Technology Policies in Developing and Transition Countries: Reform and Technological Co-operation with Europe

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EXECUTIVE SUMMARY

Co-ordinator:

Dr. Sanjaya Lall

Queen Elizabeth House, 21 St. Giles

Oxford OX1 3LA, UK

Conceptual Introduction

Wolfram Latsch

This survey introduces the central concepts in technology policy. We start with neoclassical models, where the literature of the economics of technology is still very limited. The most relevant contributions centre on information as an economic good, and concepts of market failure are crucial here to the role of policy. The issue of investment in R&D leads to theories where technological progress is determined by microeconomic decisions taken by rational agents: the 'endogenous' growth school. We then consider non-neoclassical models, traced to Schumpeter but with more recent contributions from the 'evolutionary' schools. The empirical analysis of technology policy is considered for the 'national innovation systems' (NIS) school and other approaches.

Theory and Technology Policy

Neoclassical: In textbook neoclassical models, the assumption of perfect markets ensures that the ensuing equilibrium will be Pareto-efficient. Technology describes the production sets of price-taking firms; it is perfectly codified in a universally available 'book' of blueprints, with a set of techniques appropriate for all firms under all possible factor price combinations. This technology is exogenously given, and all firms have perfect information on its nature and characteristics for all time. In this highly restrictive model, policy has no role: any interference with perfect markets can only be distortionary.

Conventional information theory (where information and technology are synonymous) suggests, more realistically, that the special characteristics of information make it unlikely that markets will be efficient in the textbook sense. Technology is treated as endogenous, agents are differentiated by the information they have, and can affect outcomes. Information cannot be produced ('innovated') or distributed ('diffused') in optimal amounts in free markets, because it has 'public goods' features, increasing returns and externalities. In these imperfect markets, the outcome is often indeterminate and ambiguous, with multiple equilibria abounding under many model specifications.

A large number of factors contributing to deviations from welfare optima were introduced in recent models, and results were generally not generalisable. For instance, if benefits to adopting new technology increase with the number of adopters, there may be co-ordination failures and resulting adoption and diffusion pattern may be socially suboptimal; thus, information provision or subsidies may be called for. Or, some market power or monopolisation may be required to allow innovators to recoup their investment (the Schumpeterian trade-off), with the static welfare costs of monopoly counterbalanced by dynamic benefits of innovation. Or, the introduction of uncertainty into the innovation process could by offset by introducing an 'innovation possibility frontier' (a particular probability associated with investments in technological change), and therefore the possibility of a rational investment decision could be retained.

'New' growth theory seeks to endogenise technological change into growth models. There are a wide variety of such models, with increasing returns and externalities playing the critical roles in economic change (the underlying ideas are often not new, incorporating such concepts as cumulative causation which have been part of development economics for a long time). However, they remain at too high a level of generality to yield practical technology policy conclusions. They rely on restrictive 'steady-state' assumptions and rational expectations (which fits awkwardly with innovation and are particularly incongruous in the presence of the multiple equilibria and path-dependence). They pay no attention to institutions, history, and transactions costs which are fundamental to the explanation of the growth and technology development experiences across countries.

With all these refinements to the basic neoclassical model, policy implications to some extent become contingent, dependent on whether the government faces the same informational constraints as private agents. However, the basic robustness of the neoclassical model is taken as given, and relaxing some of its assumptions (so giving rise to 'simple' market failures) does not challenge its fundamental premises: it is possible to return to equilibrium with some feasible interventions.

Modern information theory: Neo-Keynesian information theorists mount a more fundamental critique of neoclassical theory, arguing that market failures are not 'simple' and that the very conceptualisation of markets underlying the competitive framework is erroneous and misleading. Without uncertainty and informational problems (incomplete information, imperfect information, and asymmetric information) the economy as we know it may not even exist: a complete set of markets is fundamentally and in principle at odds with the very notion of innovation. There are diffuse, 'atmospheric' externalities, giving rise to a general presumption that policy can be potentially welfare improving. With such 'complex' market failures the co-ordination problem is likely to be greater, and government intervention may be necessary to avoid a low-level equilibrium trap. The government's special position is that it can enforce rules and agreements, and may therefore be able to overcome myopia induced by strategic uncertainties and principal-agent problems. However, the emphasis is more *evolutionary*, focusing on the unfolding of the economic process itself, rather than on the construction of aggregate co-ordination models. Government itself faces severe information problems, and comprehensive planning is unlikely to be feasible, though more limited interventions may be.

Evolutionary theories: The key concepts in evolutionary theories are *variety*, *mutation* and *selection*. History and path-dependency play a very important role here: technologies develop along particular trajectories, which themselves are governed by particular technological paradigms. The notion of 'technology' is very broad, to include knowledge, problem-solving techniques, and decision-making rules. The behavioural basis of much evolutionary reasoning is bounded rationality, which emphasises human decision-making and information-processing constraints. Optimisation is not feasible in a complex environment in which there is strategic interaction among agents, and therefore firms make routine-based decisions based on 'satisficing'. Learning in a fuzzy, uncertain environment is the critical element of technology development, with large and continuing asymmetries in learning between firms and countries. Institutions and policies matter. Static efficiency may not automatically be translated into dynamic growth. The evolutionary approach is fundamentally different from linear neoclassical reasoning: it analyses the feedbacks among various stages of learning and the historical contingency of the process. It is often based on case studies of particular innovations and firm-level or industry-level studies of the adoption of technologies. The approach is historical in spirit, founded on case studies of firms, industries and countries, where it underlines the specificities of each. From this emerges a much more complex picture of technological processes than that implied in the equilibrium approach.

The policy implications of the evolutionary approach are that the S&T system should be *pluralist*, not try to 'pick winners' but emphasise micro-level diversity. Technology and innovation policy should be concerned with dynamic competitiveness rather than static welfare, and should design 'appropriate' co-operation between firms and science/technology institutions as well as set up relevant institutions: in short, a climate in which co-operation and competition are balanced, and in which subsidies and competition coexist such that the incentive to innovate is maintained.

National Systems of Innovation: The NIS approach is basically evolutionary, focusing on information and knowledge as the most important resource, and on learning as the most important process, for growth. Learning is 'interactive' and 'socially embedded', links between firms as well as between firms and institutions being critical and country-specific. The definition of innovation is broad, covering all processes by which firms master and implement new technologies and organisational practices. Little is, however, said about the need for specific government policies: the emergence of competitive and dynamic businesses is taken to be 'spontaneous' and country specific. The approach admits the importance of strong educational and training systems in areas in which the country is competitive, and macroeconomic stability paired with strong incentives to export, but otherwise does not try to assess particular market failures in technology development and how they may be overcome. As a result, this approach tends to stay at a rather descriptive institutional level, with broad pictures of the components of the innovation 'system' unrelated to specific policies and learning outcomes.

Technological Capability approach: The TC approach was developed to guide firm-level analysis: it complements more aggregate approaches, and attempts to construct microeconomic foundations for industrial and technology policy. TCs are the skills (technical, managerial or organisational) that allow firms to utilise equipment and information efficiently. Such capabilities are *firm-specific*, institutional knowledge composed of individual skills accumulated over time which are not merely 'linearly added', but contain a synergistic element.

While also based on the evolutionary approach, the TC approach links firms to policy *via* the markets (skills, information, finance, inter-firm links and so on) within which learning takes place and the ways in which policy can improve and co-ordinate them. The view of market failures is closer to new information theories than to conventional neoclassical economics, and some authors seek to explain the evolution of national capabilities and industrial success by applying this framework. Indeed, the analytical procedure is to find successful policy experiences and reason backwards to what the market failures were that governments were trying to address. However, the extent to which particular policy outcomes can be transferred, say from successful East Asian economies to less successful developing countries, is not clear and is not tackled at any length.

Conclusion: In terms of S&T policy, 'simple' market failure models tend to incorporate policy as a purely pedagogic device: introduce market failure, and let the government correct it. This is particularly evident in early studies of market failures where optimal taxes or the creation of property rights are discussed. Essentially, informational and market failure is a localised pathology, and many outcomes are constrained Pareto-efficient, requiring no government intervention. The more 'realistic' the informational assumptions (particularly if the government is constrained to the same information set as private agents), the less general the resulting policy implications. This is a feature of both evolutionary and the 'information-theoretic' models. The NIS approach stress the contingency and specificity of particular techno-economic systems, and are mostly silent on specific policies. The TC approach draws upon the experience of successful countries to derive generalisable policy conclusions, but leaves out considerations of how other countries can mount similar policies to arrive at similar outcomes.

Empirical Studies of S&T Policy

Little research has been published in terms of systematic comparisons of S&T policies and systems between different countries. The countries studied most often are the UK, USA, France and Germany, where there is an extensive literature on industrial evolution and technological change. But these studies are not comparative in drawing policy lessons: they are descriptive and historical, and do not attempt do identify and promote 'successful' approaches. The conclusions drawn mostly point to the importance of country-specific circumstances, history, and culture. Two recent comparative contributions are edited by Porter and Nelson, both with large numbers of country studies and a similarly broad scope, going beyond the analysis of S&T policies. Both focus on the interplay of institutions and policies in shaping production and innovation structures. The most important conclusions to emerge from the empirical studies reviewed are:

- S&T policies depend on the level of development of a country, but they also play a crucial role in determining that level of development.

- The balance in research and development activities tends to shift between the public and private sectors in the course of development. A number of institutions support the S&T development process, many of which are located between the individual firm and pure public organisations.

- Technology development takes place not only at the technological frontier, but also in the course of technology adoption and diffusion. A broad array of skills and education are required in order to facilitate absorption of technologies; probably the most powerful national S&T instruments are education and training policies.

- High incomes can be generated in industries not at the frontier of technological development, and it is not desirable for every country to be engaged in scientific research and development.

- Decisions regarding technology and innovation are affected by a wide range of polices which are not S&T policies *strictu sensu*, such as trade, industrial, and education policies.

- The precise nature and target of science and technology policies may be less important than the efficiency with which they are implemented.

- The effectiveness of S&T policies is debated in developed countries; in developing countries they may not have as large an effect on technological development as other policies.

- Many successful S&T institutions are built on previously existing institutional arrangements, so that a strong institutional continuity is discernible in many developed countries.

- The inherent uncertainty of much technological and innovative activity implies that, whatever policy stance one wishes to take, it needs to be flexible. But the complexity of the process also requires that (often *ex post* wasteful) variety must be encouraged, and experiments carried out.

- Governments cannot target many factors in a national innovation system (especially certain cultural and attitudinal factors). Many desirable features of national innovation systems have emerged fortuitously and seem to be rather diffuse.

- Government policy is almost inevitably 'selective' to an uncertain degree. This is partly due to the problem of designing policies in a complex environment where these may have unintended effects. Resource constraints make it necessary to prioritise certain areas of intervention.

- Protective policies have been important in most industrialisation episodes. The extent of protection is not easily gauged, and government intervention in general suffers from the same problems of assessment and evaluation. 'Efficient' protection has often been implemented by 'efficient' governments that can credibly mount a policy of eventual opening up.

TRADE PATTERNS AND TECHNOLOGY

Paolo Guerrieri

This chapter analyses changes in the long-term trade patterns (1970-95) of Mexico, Greece, Turkey and Hungary to assess their evolution of technological capabilities, and the potential role of Greece, Turkey and Hungary in European integration. The aim is to point out the structural changes that are likely to have significant consequences for these three countries in the division of industrial activity in Europe. We use a 'structuralist-evolutionary' approach to development, with a central role assigned to dynamic efficiency, technical infrastructure and an efficient process of generation and diffusion of technology.

A disaggregated analysis of the trade patterns of the four countries shows significant changes in the commodity composition of their trade as well as different patterns of evolution over time. *Turkey* had significant changes in its trade specialisation and composition up to the second half of the 1980s, mostly by expanding 'traditional' exports. In more recent years, however, a much less favourable trade performance has emerged, accompanied by stable trade specialisation and relatively stagnation in medium-high technology sectors.

Greece shows relatively poor trade performance and few structural changes over the period. Its trade specialisation remains traditional, dominated by exports of raw materials and labour-intensive goods.

Hungary has followed an intermediate course, changing and upgrading the composition of its trade in the first half of the 1990s, with significant progress recently in medium-high technology sectors. However, the results so far in terms of trade performance (export growth) have been disappointing.

Mexico differs from the other three countries by the unique evolution of its specialisation patterns over the period. It was dominated by external shocks, which led to different phases of domestic adjustment with regard to trade and industrial restructuring.

The general picture emerging from the analysis of trade patterns is not very positive for the three economies around the EU. The trade and production structures of Greece and Turkey remain backward, with only a slightly more positive structure for Hungary. In all three cases, comparative disadvantages continue to be concentrated in sectors with the highest technology content. These weaknesses may be a cause for concern in the context of their integration into the EU.

In order to improve their position in the European division of labour and create endogenous sources of technological accumulation, 'supply side' upgrading will have a vital role to play. A major role can also be played by technology transfer resulting from closer integration and links with major enterprises in the EU. Various channels have been used to strengthen these connections. Among these, the role of FDI as a source of restructuring and technological changes has been rather limited up to the mid-1990s, with the exception of Hungary in recent years. However, local skills, infrastructures and institutions have to be upgraded to benefit from high-value EU FDI.

Accessing Foreign Technology

Carlo Pietrobelli and Andrea Mariani Bartolini

This chapter analyses the various forms of international technology inflows to the four sample countries in their process of development or transition to a fully-fledged market economy. The paper considers 'internalised' forms of technology transfer, such as foreign direct investments (FDI) and inter-firm alliances and co-operation, and 'externalised' forms such as licensing and 'outward-processing trade' (OPT) by Western European firms. Evidence is presented for each of these technology flows for the relevant periods, including liberalisation years as well as years of (incipient or consolidated) integration with the European Union (and the US for Mexico). The comparative analysis illustrates the wide variety of possible ways to acquire foreign technology, and the different requirements for a country's industrial and technological development.

Greece appears as an 'early opener' within the context of European integration, but it has not been very successful in attracting foreign investments. Moreover, FDI has persistently concentrated in activities with low technology, with no signs of structural change towards higher technology sectors. Licensing of foreign technologies has also been relatively limited, and the OPT arrangement cannot apply to Greece. This manifest inability to link with technologically dynamic foreign enterprises may be a crucial obstacle to the country's technological upgrading and development.

Mexico has received large foreign investment inflows for several decades, and is characterised by a broad variety of inter-firm relationships and alliances. However, the relationship with the EU is less important for the Mexican economy than that with the US, a tendency strengthened by the NAFTA agreement. The evidence on large foreign technology inflows is promising for the country's industrial and technological development, but it remains to be seen the extent to which these flows will translate into effective deepening of local technological and industrial activities.

Hungary has been the 'late-opener', but is now very welcoming to foreign investors. It has been one of the most successful countries in its region in attracting FDI, and the sectoral distribution shows a large presence of advanced activities such as machinery and equipment and chemicals. It has also used OPT arrangements intensively to link up with European firms and gain access to their technologies.

Turkey opened earlier than Hungary, but FDI stayed at very low levels by international standards for many years. However, in recent years FDI has risen, and its sectoral pattern looks promising for the country's technological development. The share of FDI in traditional products has fallen over time, whilst the share of science-based activities has increased; FDI in scale intensive products has stayed relatively high throughout the period (1975-95). Moreover, it is using OPT in textile and garments effectively to build up local production capabilities and raise local value added.

In order to draw out the implications of the different patterns of access to foreign technologies, it is necessary to take into account the macroeconomic context, the S&T structure and industrial performance; this is done in the individual country studies.

Annex to Accessing Foreign Technology:

Technology Transfer by FDI: Manufacturing FDI by Italian SMEs in Hungary

Marco Mutinelli

This annex provides empirical evidence on the direct and spillover effects of manufacturing FDI as a mechanism to promote technology transfer, focusing on manufacturing subsidiaries of Italian SMEs in Hungary.

After a brief discussion on the general pattern of Italian FDI in manufacturing, the annex analyses the motivations of a growing number of Italian SMEs, mainly in low- and medium-technology industries, that invest in Central and Eastern Europe. A hybrid model emerges, in which strategies aimed at gaining market share or enriching technological skills are combined with the relocation of labour-intensive activities and/or joint ventures aiming to supply the foreign partner with low-cost products. Market-seeking investments mainly concentrate in specialised supplier and scale-intensive industries, while in traditional industries the main reason for FDI is the search for low-cost labour. The internationalisation of smaller companies is not always the result of deliberate strategies in response to changes in the home country's comparative advantage or the emergence of a new market. Sometimes, they result from stimuli received from international competition which force firms to abandon traditional export-based strategies; in some cases, FDI by SMEs aims at exploiting profitable market gaps and short-term shortages.

The analysis of technology transfer and spillover effects of Italian SME FDI (20 cases) in Hungary gives a positive overall result in terms of access to new technologies, upgrading of suppliers and participation in global production systems. In 17 cases, Italian entrepreneurs considered the investment as "positive" or "fully positive" and expressed their willingness to deepen their commitment in the Hungarian affiliate. In most cases, however, 'technology transfer' in a strict sense has been limited; FDI has been associated more with significant improvements in labour productivity by the transfer of manufacturing, organisational and managerial skills.

Imports of Machines and Transfer of Technology

Giorgio Barba Navaretti

This chapter analyses how trade integration with more industrialised countries has affected technological choices, as measured by imports of machines (embodied technology), in the sample countries. This analysis represents the first attempt to use machinery imports as a measure of technology transfer. The first part of the paper spells out the main underlying hypotheses. The choice of technology is expected to be determined by two set of factors: relative prices and the overall level of technological capabilities and human capital in the importing country. Liberalisation and integration with more industrialised countries may affect this choice in two different ways: sample countries are expected to downgrade their technologies in order to exploit their existing comparative advantages in cheap labour; at the same time, the quality requirements of export markets may force them to upgrade their technologies within these labour-intensive activities.

General data on total imports of machines at the aggregate level show broad trends in the upgrading of embodied technology; however, they show little about the technological levels involved. We therefore need to classify machines according to their technological complexity, and do so for the *engineering* and *textile industries*. In the case of textiles, we can also relate machinery imports to the exports of specific products.

It appears that liberalisation affected technological choices in the sample countries in the expected directions. There was an upgrading of technology (represented by imported machinery) in industries where the countries had accumulated sufficient technological skills and exploited enough scale economies to have established genuine competitive advantages Otherwise, countries achieved export competitiveness by downgrading the quality of their products and moving towards simpler technologies. In a liberalised setting, the choice of technology is clearly driven to a large extent by the requirements of the export market.

Hungary: In the aftermath of liberalisation, Hungary invested heavily in the engineering sector, where it had a long tradition and considerable accumulated capabilities. Its competitive strategy for the European market was to raise its capabilities, which it did by upgrading the technological content of imported machines. By contrast, in textiles, where its competitive edge lay in cheap labour, it downgraded its technology. Hungary completely changed its pattern of trade specialisation after liberalisation. It used to have a dual export structure, with traditional products sold in the industrialised world and technology-intensive products like motor vehicles sold to CMEA countries. Since liberalisation, when Europe became the main export market, traditional products were phased out, and efforts focused on the products that used to be sold to the CMEA. Such a strategy required a strong technological effort to upgrade the productive structure.

Turkey has been able to strengthen its competitive position in the textile industry by gradually moving into more capital intensive stages of production (e.g. from clothing to textile production) and by increasing automation in existing facilities, essential for it to preserve a competitive advantage. However, Turkey has been less successful in diversifying its export structure towards more technology intensive products. The skill intensity of the machines purchased by important non-traditional sectors like motor vehicles has been stagnant. Thus, although Turkey has improved its comparative advantage in industries like motor vehicles, it apparently has not done so by upgrading its technology.

Greece is a disappointing case. Notwithstanding EU membership and higher per capita income than the other three sample countries, Greece has been downgrading its technologies throughout the period. In textile and clothing the situation appears particularly worrying. This is the major export item of the country, but Greece is losing competitiveness, as shown by 'revealed comparative advantage' indices since the early nineties. Despite its high labour costs, Greece is not upgrading its technologies. Imported machines have much lower skill content today than in 1988; and, in 1996, all other sample countries except for Hungary imported more skill intensive machines than Greece. In metalworking, Greece has been importing less technology-intensive machines throughout the period. Greek export performance is poor, and consistent with the lack of technological upgrading as manifested in machinery imports.

It is difficult to analyse *Mexico* properly, since the EU data used cover only part of its imports. What the data show, however, is that Mexico has upgraded its technology in both industries. The upgrading of engineering technology is consistent with the reorientation of trade that followed the NAFTA agreement: the Mexican automobile industry is now highly export-oriented. Moreover, strict rules of origin have forced an increased process of vertical integration and thus new foreign investments in the country.

Policy implications: Liberalisation does not automatically lead to technological upgrading. It takes time and accumulated experience before a developing country integrating with an industrialised one is able to improve its competitiveness through technology upgrading. Of course, moving to simpler technologies in the aftermath of liberalisation can be a desirable means to boost competitiveness, but this cannot remain the country’s long-term technological strategy. S&T policies have to be developed to facilitate the upgrading of the competitive structure, by reducing the costs of accumulating skills and undertaking technological activity. When countries already have a comparative advantage in more sophisticated industries (Hungary in metal working), policies should be targeted so as to strengthen this advantage and ease the interaction with firms and customers in their industrialised counterparts.

Greece

Theodosios B. Palaskas and Manos Antoninis

Introduction

This report examines the institutional structure providing technological assistance to the Greek manufacturing. Using surveys of a number of industrial science and technology institutions and 25 industrial firms contacted in late 1996 and 1997, this report analyses how these institutions adapted to the needs of manufacturing, the main technological problems and constraints faced by the industrial sector, and the public support it would need to reach technological parity with the rest of the community. The six industries chosen were dairy products, plastic tubes, textile yarns and fibres, telecommunication equipment, cables and apparel and clothing.

Greece displays characteristics of a developing economy in terms of industrial technology and trade structure. Research has atrophied and technology transfer has been neglected. Trade is characterised by the dominance of low value-added exports (agricultural products, minerals, simple manufactured products) and imports with high technology content, facilitated by high tariffs for final goods and low protection for raw materials and equipment imports until Greece entered the EEC. Import substitution guided policy makers in the after-war years, when basic industrial activity was introduced and incentives for foreign direct investment provided. Greece achieved substantial growth rates until 1974, which transformed it from a rural into a semi-industrialised economy in a period of twenty years. Import substitution was extended up to 1986 to facilitate its entry to the European Community, insulating industry from the structural changes needed to become fully competitive. When protectionist measures were withdrawn in 1988, Greek industry was suddenly faced, not only with an unprotected market, but also with unfavourable macro conditions resulting from the convergence programmes of 1992 and 1994 to meet the Maastricht treaty targets.

Greek manufacturing went through a phase of de-industrialisation after the early 1980s. The share of manufacturing in GDP declined from 21.4 to 18.6 per cent during 1980-90, and further to 16.8 per cent in 1993. The production index for all goods, capital goods and consumer goods has stagnated over the past 15 years. Investment, affected by adverse financial conditions and macro instability, remained below previous levels. Employment dropped in traditional industrial centres. A number of large companies went bankrupt in the late 1970s and early 1980s, often due to mismanagement; the former socialist government attempted to save some of them, which remain today as problem enterprises. Productivity stagnated through the decade following accession to the EEC. Net profits were negative through much of the 1980s.

It is only in the most recent years that the situation has begun improving, reflected in the recovery of financial indicators from the mid-1980s slump., Nevertheless, the climate was not very favourable to finance the required restructuring. Thus, liberalisation took place under adverse conditions for research and innovative activities.

S&T Policy

There was no formal science and technology policy in Greece until the late 1970s. The Greek Standardisation Organisation was established in 1976, followed one year later by the Greek Organisation for Small and Medium-Sized Firms and Handicrafts. In 1977 the first organisational structure was created through the law 706/77, which established the parallel operation of three bodies: the Scientific Research and Technology Agency (SRTA), the Ministerial Committee on Scientific Research and Technology and the Advisory Board.

The Ministry of Education had dominated research till this time, though universities had not established formal research departments and technical colleges were still in their infancy. These developments were accelerated in the 1980s, assisted by the European Community. The focus was on project funding to promote utilisation of results, industrial research to raise R&D demand, institutional modernisation of the national research framework to promote merit and competitiveness, and above all linking the research system (universities and institutions) with production. In 1982 the Ministry of Research and Technology was created to delineate and implement national policy in scientific research and technology.

In 1985, the Ministry was transformed into the General Secretariat of Research and Technology (GSRT) of the Ministry of Industry, Energy and Technology. The 1985 Law for the Development of Scientific Research and Technology dealt with the planning and co-ordination of research, the institutionalisation of funding and evaluation, the organisational structure of research centres, the careers of research scientists, the relations of research centres with each other and with universities and the rules regarding the transition to the new institutional order. The Programme for the Development of Industrial Research (first initiated in a pilot form in 1985 and introduced in full scale after 1986) was meant to arouse firms' interest in research and stimulate co-operation with the new S&T infrastructure. In 1987 a new law modernised the obsolete patent system. The Industrial Property Organisation was set up to grant patents and certificates and document technology transfer contracts. Fiscal incentives for research were introduced: accelerated depreciation, tax allowances and other measures. The Small and Medium-Sized Firms' Organisation established the Innovation and Technological Development Directorate, five decentralised Innovation Centres and a Centre of Product Design. By the end of 1987 the second 5-year Plan for the Development of Research and Technology (1988-1992) was launched.

S&T Institutions

The Greek technology system comprises the policy making unit (GSRT), the technology and research bodies supervised by GSRT, academic research centres and universities, other public research and technology institutions, and private research and technology institutions. The field survey included institutions from every group as well as the apex body GSRT. Most were selected because of their co-operation with sample firms, and information was obtained from both sides. A few others were selected for their system-wide influence, to gain insight into the way the science and technology infrastructure functions. Apart from these criteria, the selection of the institutions was random. The institutions covered were as follows.

The *National Documentation Centre* (NDC), responsible for the development of information networks, is based in the National Research Foundation. It is setting up a National Information System, including the creation of national data bases, incorporation of foreign data bases, development of information technologies and co-ordination of libraries systems and the organisation of the Innovation Relay Centre, whose purpose is the utilisation of research results, the transfer of technology to small and medium size firms and the support of Greek firms' participation in EU R&D programmes. The two main reported problems in its operation were the over-concentration of responsibilities in a rather understaffed agency, and the difficulty in marketing its services to the business community.

The Technology Park of Thessaloniki (TTP) has so far offered services as a business incubator, training centre and small-scale technology transfer. It also participated in the Regional Technology Plan for the province of Central Macedonia and the Inter-Regional Information Society Initiative (IRIS), which produces a grid of sensors and reference points to transmit data on environmental quality. There are three other technology parks in Greece. One based in Iraklio, Crete, operates in the same way. The Athens and Patra parks follow traditional routes as academic research centres, which are trying to open their doors to manufacturing

The Laboratory of Industrial Economics at the National Technical University of Athens (IE-NTUA), the oldest research centre of its kind, aims to promote economic and management knowledge to engineering students. Its research focuses on energy economics and environment, management and choice of technology in manufacturing firms, and social dimensions of technology with an emphasis on telecommunications and informatics. The energy dimension arose because of EU funding in programmes such as Joule and Thermis, while domestic demand guided research in telecommunications.

Atlantis, based in Thessaloniki, is a new company which has undertaken a major project of technological awareness, but suffers from the scarcity of trained personnel. After the initial phase of organising business environments, business plans and quality control processes, it undertook a major project of technological awareness, which brought it close to the technology market.

The Food Technological Development Company (ETAT) is a case study of repeated policy failures. It is a small company, employing only eight people, and has been constantly running at a loss. It faces all the negative aspects of public institutions such as the rigidity in employment procedures and the inability to balance different public bodies. It does not have marketing personnel and has failed to produce even a bulletin to inform potential customers of their existence.

The Dairy Research Laboratory at the Agricultural University of Athens (DR-AUA) faces strong demand for its services from some of the most competitive and R&D intensive manufacturing firms in Greece. It has benefited from being situated at the same building as the National Milk Committee, which disseminates information on the existing rules to dairy producers. While the Laboratory does not have any authorisation to perform official quality controls (which would boost its status) it engages in applied research and the provision of technology services. National and European funding appears is playing an ideal role in supporting existing research projects, rather than simply raising awareness of the need for technological development. Good networking, based on personal relationships and the success of previous partnerships, enables the Laboratory to achieve its aims.

The Clothing, Textiles and Fibres Technological Development Company (CLOTEFI) is doing well in the identification of its client base, and has managed to develop its research potential in collaboration with the National Technical University of Athens. CLOTEFI was founded as part of the effort to make national technology policy serve industrial policy needs and to benefit from the possibilities offered by the European Community. By 1995, CLOTEFI was able to become financially independent of national and EU sources. The company has tried to collaborate with its clients, it participated in studies of the Ministry and the Chamber of Industry and Trade and it was also a link in the Innovation network in an effort to identify the needs of its potential market. Its case is reviewed further below.

The Federation of Industries of Northern Greece (FING) is lobbying for technology services for textiles in Thessaloniki. Its influence is constrained by the limited participation of potential members.

The National Agricultural Research Foundation (NAGREF). In 1989, all institutes operating under the auspices of the Ministry of Agriculture were integrated in NAGREF. However, as a consequence of a conflict of interests over the control of research funding, NAGREF's policy is not controlled by researchers themselves. According to the representatives of the Institute, the roots of this conflict are with the Ministry of Agriculture. Resources that should come straight from the Ministry of Agriculture in order to finance its long-term research programmes have been blocked. The continuing rivalry with the Ministry has even affected hiring, which has been frozen since 1985. Moreover, co-operation with manufacturing firms has been scarce and only as a result of the requirements of the national R&D programmes. In the past year, only two firms had been customers of the Institute.

The National Research Centre of Natural Sciences (NRCNS). Despite the fact that the Centre has been reformed and its member institutes forced to seek private partners, not all parts have been equally affected. Some laboratories have been more successful in attracting resources beyond strict budgetary limits and have ended up subsidising less capable or less industry-oriented laboratories.

The Department of Chemical Engineering at the National Technical University of Athens. As public funding of tertiary education has been curtailed, academics have to look for additional funds to maintain their research programmes and modernise laboratory equipment. Some centres, for which there is practically no domestic manufacturing base, have to rely increasingly on EU networks, such as the Laboratory of Thermodynamics and Automated Control at the Department of Chemical Engineering at the National Technical University of Athens.

The Laboratory of Agricultural Constructions at the Agricultural University of Athens (AE-AUA) is active in the area of agricultural waste products and greenhouse technology. However, only six firms have in fact co-operated with the Laboratory in the past eight years.

The relevance of the national scientific and technological structure to manufacturing industry can be judged by three criteria: the solution of technical problems in the industrial sector, the development of usable technology, and the provision of training. Greek technology institutions are dealing with at most one dimension at a time and there is little complementarity in their activities. None of those studied in this survey seems to be able to offer services to a wide range of firms and generate a process of technological modernisation.

We singly out one case study as moving, if not always successfully, in the right direction: *CLOTEFI*. It is distinguished by the wide applicability of its activities to manufacturing and by the close research relationship it has developed with an academic institution. Its experience summarises the current state of Greek technology policy and the attitudes of the people involved in it. CLOTEFI's revenues are split between national and European RTD programmes and contracts with private firms, with the latter rising in importance over time. CLOTEFI has been involved in a large number of sponsored programmes to push firms to modernise their production capabilities:

- Innovation Management Techniques : a project involving the modernisation of organisational capabilities and the facilitation of technology transfer for about fifteen firms.

- A project on the application of the ISO 14000 environmental quality control system
- RETEX : projects on the application of the ISO 9000 quality control system
- Innovation : a project in collaboration with the National Documentation Centre and the Thessaloniki Technology Park to register the technological level of about thirty firms.
- ADAPT : a project on technology audits in ready-made clothing firms.

The response of participating firms has often been disappointing, surprising given that all these initiatives are heavily subsidised. CLOTEFI believes that some subsidisation is essential if the sector is to become technologically aware. It also believes that a strong cohort effect will affect business adaptability, as a younger generation of managers gradually takes its place in basically family-run firms: it is with these firms that interaction is sought.

The lack of co-ordination at the level of overall technology policy is a constant threat. Despite an articulated and consistent strategy, the development of CLOTEFI has been held back by continuing rivalry with respect to its future ownership status between the two institutions under whose aegis it operates, the GSRT and the National Technical University. The implementation of the business plan has consequently been postponed. The financing of the business plan comes from two major structural programmes: the Operational Programme for Research and Technology (40%), which will cover investment in research equipment, and the Operational Programme for Industry (60%), which will mainly cover the expenses for certifying the services provided by the laboratory. The first fund is administered by the GSRT, while the second by the GSI (General Secretariat of Industry), both of which belong to the Ministry of Development. However, the delay in settling the organisational issue with the GSRT affects the pace at which CLOTEFI absorbs the budgeted funds.

In short, the Greek technological system has not become self-sustained and independent of external support. It relies heavily on a complex and unstructured, often unrelated, system of subsidies. A minimum set of institutions exists and there does seem to be an urgent need to create new ones. What is essential, though, is to expand the scope of their activities and apply horizontal policies in generic areas (like engineering and automation) and technologies that can have spillovers in all manufacturing.

The dissemination of domestic research output is also an area where public policy has failed to make an impact. Existing research potential has not been utilised by industry or has leaked to foreign industries, which have the mechanisms to receive and transform research output to their own benefit. There are, however, signs of change. There is increasing awareness among technology institutions of the need to approach manufacturing industry and fulfil the role for which they have been set up. Interviews with firms suggest that they are also, in certain conditions, maturing gradually in technology activity and so will demand more technology services.

Firm Responses

Almost all sample firms undertook initiatives to respond to the challenges of liberalisation. Overall, the analysis shows that the Greek accession to the EU had a profound positive impact on technological upgrading, in spite of the adverse macro environment, high interest rates and the high exchange rate. A lot of technological improvement was acquired by firms in embodied form through highly subsidised investment, directed mainly for modernisation and expansion, and undertaken in the most technology-intensive sample sectors. Almost all sample firms, independently of size and technological intensity, are involved in some type of formal technological effort, aiming to adopt offensive strategies like new product introduction and process improvement. The survey shows that sample firms are aware of the need for certified quality control systems for their products to be competitive.

A small number of firms have developed contacts with domestic or foreign institutes for technological upgrading. The high cost of services and the lack of understanding of the needs and problems of the industrial sector are the main problems faced by firms in their collaboration with technology institutes. Most firms are not positive about the usefulness of their interaction with the institutions.

Technology institutions have in general played a very small role in the technological modernisation of Greek manufacturing. Instances of co-operation between them and the firms are few; even fewer are spontaneous (not initiated and subsidised by national or European schemes). There is a risk that once these funds dry up there would be little demand for their services.

Policy implications

The most obvious impact of recent policy changes on technology has been in academic research institutes, where forces of competition and foreign influence have definitely been felt. In many cases this has been accompanied by economically useful outputs. Nevertheless, the application of domestically produced research has lagged. One of the main problems remains inefficient dissemination to potential users: there are few research units willing to associate with industry. In Greece, a country still characterised by traditional social relations, the information and credibility gap has been generally filled at a personal level. However, technological modernisation cannot be carried out on this basis for long: the process has to be broadened and made more systematic.

The European Union has embarked on a series of orientation projects to help overcome these problems, with some apparent success. However, problems remain. The methods of tracing potentially innovative small firms are expensive; because of the irregular pace with which projects are undertaken, there is a risk of leaving newer firms out while early entrants are recognised and funded by the programmes. There is therefore an urgent need to set up organised data bases of current research in the national research centres and technical support needs of firms, to which entrepreneurs can resort when looking for solutions. Such initiatives should not remain the prerogative of the GSRT, which has focused in the past on linking research institutions, universities and laboratories; industry itself, with its associations, should be intimately involved in the design and management of the data base.

The promotion of collaboration in technology can be stimulated by subsidies, but this does not usually lead to genuine interaction. To reduce the risk of rent-seeking applications, it is important to apply stricter criteria for the utilisation of results or employ more specialised personnel to judge applications. The GSRT does considerable reviewing of high-technology investment proposals, but the evaluation process does not have any clear guiding principles and external reviewers have varying degrees of interest and responsibility. It is important to provide a set of clear, specific criteria that all reviewers can follow.

Greece also suffers from a lack of prioritisation in technology policy making. Since the technology system cannot support all industries equally, it is important to concentrate more resources on those activities that the market has singled out as ‘champions’. Obviously this leaves out the broader issue of restructuring and technological transformation; however, such issues cannot be addressed with simple policies, as they are the result of slow social processes or of rapid and massive policy interventions. But for such a change to take place, a fundamental change in policy approach must precede it. Current policy initiatives, which have focused on setting up institutions with meagre endowments, do not reveal such a fundamental shift in priorities.

Hungary

Henny Romijn and Ildiko Taksz

Introduction

Hungary differs from other countries in this study because of its recent transformation from socialism and central planning to democracy and a market economy. Raising industrial competitiveness has been in the centre of economic policy debate, and is vital to economic restructuring. Hungary's ability to make modern and high quality products will be key to expanding in foreign markets, fostering economic growth, and eventually obtaining EU membership. This study explores the extent to which Hungarian industrial research institutes and firms have adapted to the new economic environment after 1989, and identify the factors that have facilitated and constrained their efforts at technological improvement. Special attention is given to the links between manufacturing firms and S&T institutions.

These issues are explored from the perspective of both research institutes and manufacturers, based on interviews with 24 industrial firms and 13 S&T institutes in 1996. A number of other interviews were conducted with institutions involved with the management of S&T in Hungary, such as the National Committee for Technical Development (OMFB) and the Hungarian Academy of Sciences (MTA). The interviews covered current problems and prospects, levels of state support, collaboration with other actors in the national S&T system, future plans and participation in EU support programmes. Four industries, textiles, pharmaceuticals, automotive and electronics, were selected because of their different historical, market, and technological characteristics, different growth prospects, and importance in terms of technology, employment or income generation.

S&T Institutions

Economic liberalisation, transition to a market economy and privatisation have created a new and challenging environment for S&T institutions. The impact on R&D institutions was especially severe because of the erosion of the pre-1989 support structures. All segments were badly affected, especially sectoral industrial research institutes, many of which went bankrupt. The institutions under the aegis of the Hungarian Academy of Sciences (MTA) and universities also suffered, but to a lesser extent: the government gave greater preference in its financing to maintaining basic research. Most of the 13 R&D basic and applied institutes in this report thus represent successful adaptation to the changes.

Survival has dominated the agenda of most institutions, forcing changes in attitudes and activities. There are significant similarities between institutions in problems and survival techniques. Adaptation often involved significant downsizing of the workforce and the range of activities, stricter financial management, and a more commercial outlook through staff incentives. Key strategies for securing necessary finances included moving into consultant engineering services and increasing contract research, even for research institutes of the Hungarian Academy of Sciences, which have traditionally engaged in basic research. In most institutes, activities were concentrated in limited areas, while in other cases activities became more diversified, based on market demand. Research grants funded by OTKA, FEFA and various EU co-operation programmes (PHARE, TEMPUS) became increasingly important. Additional income, following large cuts in budgetary support and the low demand for contract research from companies, also became crucial to survival.

The traditional institutes' recent performance has depended on internal and external factors. Internal ones include size, quality of the work, marketing and financial management. In-house research laboratories of manufacturing firms, domestic or foreign, were the best positioned. Others had to develop marketing abilities, totally absent in the socialist system. The main external factor was the ability and willingness of industry to make use of their services. This varied by the R&D intensity of the industrial sector, the firms' financial health, and their strategies for technological upgrading.

Interaction of Firms with S&T Institutions

The firm survey shows that major problems exist in all these areas, the most pressing being their financial situation. Given very tight financial constraints, R&D was one of the first things cut. Several large state-owned companies – the main former customers of R&D institutes – disappeared or went virtually bankrupt. Some large local firms developed in-house R&D; some, as in pharmaceuticals, strengthened their long tradition of internal innovation. At the same time, industry began to demand consulting and other services to upgrade efficiency and quality, such as laboratory testing facilities, help with new work methods and practices, and problem-solving. For most sample firms these activities were more important than R&D, a shift from the previous regime where the focus had been on copying foreign technologies through reverse engineering.

The outcomes of these technological efforts have been mixed, depending on accumulated technological and managerial capabilities, sectoral factors, ownership and, related to this, financial access. In some local electronics and automotive firms, the traditional product range was abandoned. Five firms shifted to technologically less demanding items, and product design activity was virtually discontinued. Some resorted to subcontracting parts for western firms to generate income. There was substantial erosion of human technological capability, as qualified, experienced engineers have left for other employment. Such firms now generate very little, if any, demand for services from research institutes.

Foreign affiliates were generally much less financially constrained than local firms, but showed little or no interest in the services of Hungarian technology institutions. The eight sample affiliates fared comparatively well, showing fast growth, new investment, and in some cases diversification into technologically complex areas. However, this process was driven by internal R&D in only four of the eight subsidiaries. In the others, R&D was very limited or absent, and the firms had no contacts with actors in the domestic S&T system. R&D was actively discouraged by parent companies because they preferred to use subsidiaries as production units and centralise R&D in existing centres, a general tendency noted for MNCs. For Hungary's longer-term competitiveness in technologically complex sectors, however, this tendency is not beneficial, since it risks becoming confined to the lower rungs of the technology ladder, implementing innovations made elsewhere. Given the long, distinguished research record of its enterprises, Hungary clearly possesses the capabilities to move into the innovation stage of many manufacturing activities.

Hungary's research institutions are gradually adapting to these changes. In contrast to their previous role of providers of R&D for large state-owned companies, they now aim to become more flexible and service-oriented. To some extent, this means reducing R&D and providing lower level technological assistance. It also entails catering to a new clientele: SMEs, which require more routine services and inexpensive tests. This requires fundamental changes in the orientation of the staff, which several have found difficult to manage. There has also been a welcome development: the recent establishment of new institutes to promote linkages between S&T actors. The *Zoltán Bay Foundation* fosters relations between enterprises, universities and MTA research institutes. In 1992, three university-related institutes were set up, one in biotechnology, one in materials science and one in logistics, modelled on the German Fraunhofer Institutes. However, given the small market for their services in industry, it will be some time before they can function like their German counterparts. However, they are already contributing to university research, a positive outcome.

Other recently established institutes are the *Hungarian Association for Innovation* and the *National Business and Innovation Centre*. The large number of companies and research units are using their services, showing their significance and relevance. The main problem in extending these services is, once again, the lack of financial resources.

Policy implications

Despite declarations on the importance of technology, financial support from the Hungarian government for S&T development since 1989 has been very limited. As far as the S&T institutions are concerned, policy has given priority to basic research and the establishment of new institutes (in particular the Zoltán Bay network) rather than the transformation of existing research institutes, which were generally (and rather suddenly) made to earn their own living. The limited state support they receive comes from OMFB mostly for equipment purchase; even for this, they must compete seriously with universities. The outcome has been a broad downgrading of research activities, though this has been offset to some extent by the emergence of a new market for more routine technology services. Public funding of S&T in industrial firms has been equally limited, all the more worrying because the internal financial resources of former state-owned firms are exhausted and a properly functioning market for development finance does not yet exist.

It is clear that in view of the high degree of market failure for S&T, state support is indispensable to the future of the whole R&D sector. As the real value of state expenditure has continuously decreased, support from external agencies such as the World Bank, the EBRD and the EU is very important. Recent financial support from the EU has played a significant role in many institutions and industrial firms interviewed for this survey. Its support had been well-received by technology institutions, which considered it very helpful for upgrading technology, technology transfer, and co-operation with the European innovation system. However, finding the appropriate and interested EU partners has not always been easy, and some institutes felt subordinate in the partnerships.

EU support has also helped firms with product development, quality upgrading and training. This support has not, however, encouraged firms to collaborate with the domestic S&T system, crucial for the future health of Hungarian industry. One reason is that EU projects require the involvement of EU partners. In some cases, there is obviously much to be gained from exchange with EU firms and institutes. However, in some cases the disadvantages outweighed the benefits. Involving western partners has been costly and has not always led to good results because the consultants sometimes lacked understanding of the problems and requirements of Hungarian firms. In fact, insistence on involving EU partners may have contributed to the erosion of the domestic support infrastructure.

EU support for Hungary's science and technology base could be made more effective in several ways. In particular, there is a need to strengthen the remains of the strong institutional network, by building linkages with firms (especially SMEs) into the design of EU research programmes. Incentives to SMEs to make wider use of R&D institutes' activities and services should also be encouraged. There is also room for more direct EU support to the industrial research institutes for staff training, research projects and equipment purchase for modernisation. In particular, they need support for providing services for which there is growing demand, such as laboratory tests for exports, consulting and training for ISO 9000 certification.

As far as EU assistance to firms is concerned, the application process should be made more efficient, and the eligibility criteria for financial assistance should be made easier. At present, many programmes have very specific objectives which prevents firms from even attempting to apply. There is a large unmet demand for services such as 'debugging' and problem-solving, which existing research institutes are well-equipped to undertake, based on their extensive experience of reverse engineering and imitation of western technology in the old regime. Although these can have a dramatic effect on productivity, they do not meet the usual project funding criteria. In general, EU funding of S&T in domestic firms holds out better prospects for linkage-building with domestic research institutes than assistance to foreign affiliates, especially when the latter are newly established subsidiaries of multinationals which do not have any past history of collaborating with local institutions.

The tasks for domestic technology policy are very similar. Although there have been fairly successful attempts to create links between the S&T system and industry (e.g. the Bay Zoltán Foundation), further encouragement is necessary. It is desirable to set up support mechanisms to industrial enterprises which wish to collaborate with R&D institutes. Aiding the technological capacities of research institutes to provide services such as laboratory testing would be very useful, though it is likely that private laboratories will arise to provide these routine functions. At the same time, it is important to fund research for which there is no immediate market demand: the German Fraunhofer institutes receive two-thirds of their budgets from the federal and state governments, since without a research base their ability to help firms will erode over time. Even the highly market oriented Asian NIEs provide substantial subsidies to their research institutions.

In the longer term, of course, the health of the S&T infrastructure would depend on the health and innovativeness of the manufacturing sector. In a period of transition, the restructuring and reorientation of R&D institutes can only be one element of the transformation of the S&T system as a whole. The strengthening of firm-level R&D and the increase in technology transfer are just as important, and the government should address their needs directly.

Turkey

Henny Romijn and Oktar Turel

Background

Full economic integration with Europe has been high on the Turkish agenda since 1980, when the country adopted a more liberal, outward-oriented strategy to replace decades of import-substitution and heavy state involvement in the economy. The EU is Turkey's main trading partner, accounting for 51 per cent of exports and 47 per cent of imports in 1996; this high level is expected to increase as a result of the Customs Union Agreement signed in January 1996. One of the main advantages of integration with the EU is expected to be growth through increased exports. However, until now Turkey's main exports have been labour-intensive, low value-added goods, especially textiles and clothing, which face poor export prospects as a result of intensifying competition from Asia and the ending of the Multi-Fibre Agreement. Its long-term competitiveness in the EU will hinge crucially on its ability to move into more skill- and technology-intensive, high value added goods and services. This transition will require large investments in its scientific and technological base. In comparison with the EU, Turkey's human capital base is poor, and it suffers from low industrial efficiency and a weak R&D base.

This study is based on surveys of the leading S&T institutions and 40 industrial firms, conducted in late 1996 and early 1997. The interviews with the S&T institutions focused on their capability to deliver various services required by industry, and identified the main constraints involved. The industry sample covers four important sectors, two highly export-oriented low-tech ones (garments and textiles); a medium-tech processing industry supplying both domestic and foreign markets (iron and steel); and a knowledge- and skill-intensive engineering subsector that was aimed at the domestic market, and is now facing stiff competition from imports and foreign-owned plants (automotive parts and complete vehicles). The interviews with firms focused on their technological capabilities, the extent and nature of technological upgrading undertaken, the main technological problems, and the extent and nature of their interaction with S&T institutions.

Data on productivity and structural change suggest that, despite fast output and export growth, Turkish industry lacks a strong knowledge and skill base. Manufacturing share in employment (32.5% in 1993) and value added (21.7% in 1993) has remained practically unchanged since 1988. The share of total investment in manufacturing remained constant until the mid 1990s, rising slowly thereafter. In the mid-90s, nearly half of manufacturing production consisted of consumer goods and light intermediates, and nearly half of manufactured exports consisted of textiles and garments. The basic metals sector was also important, but most exports were primary or simple products: the share of machinery and equipment in exports was just 6 per cent. There is thus little evidence of growing competitiveness in technology-intensive products since liberalisation started in the late 1970s; Turkey has so far exploited its static comparative advantages in cheap labour and simple technologies. One study of total factor productivity reports productivity growth of only 2.5 per cent per annum during 1977-90 (compared to 5.5 per cent for Spain and 7.4 per cent for Korea). Moreover, the main source of this growth was apparently increased utilisation of existing capital stock after the liberalisation rather than technological improvement.

At the micro level, however, there are more signs of technological dynamism. Studies of textiles and garments report significant investment in modern equipment as well as efforts to cut costs and improve products and processes: firms are responding vigorously to economic liberalisation. One reason why their activities are not yet reflected in the macro-economic statistics may be that it takes time for the results to materialise. Another may be that micro studies focus on the most dynamic firms; there are large segments where technological modernisation efforts have been much less intensive. This is likely to be particularly true of sectors in which technologies are difficult to master, there are large economies of scale, and where there is a long history of protection from import competition.

Technological weaknesses in Turkish industry can be traced to three sets of problems:

1. The S&T system: Turkey has low investments in R&D. Until now the country has relied mainly on technology imports rather than internal technological efforts. Gross expenditure on R&D has stagnated at around 0.40 per cent of GDP since the start of the export-oriented strategy (compared to 1.96 per cent for the EU as a whole in 1993). Its 8.2 full-time equivalent personnel per 10,000 population in R&D lags significantly behind the EU's average of 40 in 1995. Industrial R&D contributes only 22.7 per cent of the total, and industrial share of S&T manpower is just 17.7 per cent (1995). Though these figures underestimate total technological effort (they exclude informal technological activity), they suggest strongly that Turkish industry lacks a 'research culture'. It is estimated that only about 2 per cent of Turkish firms have R&D programmes. The bulk of R&D funds (68.6 per cent in 1991-5) is spent by higher education institutions, which employ 60 per cent of total S&T manpower. The role of public sector research institutions is limited and declining, its spending accounting for just 8.7 per cent during 1991-5, down from 28.0 per cent in 1983.

2. The human capital base: The level of education of the labour force is low. In 1995, just 3.5 per cent of the population aged 12 years and over had completed tertiary education. Of these, less than a quarter had graduated in sectors that are especially important for S&T, namely engineering (18.8 per cent) and natural sciences and mathematics (5.5 per cent). Just 22 per cent of the population above 12 years had completed secondary education, and less than 30 per cent of those had graduated in vocational and technical subjects. The quality of education, especially of technicians, is also not adequate to modern industrial needs.

3. The policy climate for S&T development: Policies for promoting technological upgrading and modernisation in manufacturing have been low on list of policy priorities. The emphasis has been on trade and financial policies aimed at restoring macroeconomic equilibrium, reducing government debt and promoting international integration. Significant export subsidies were put in place in the early 1980s, which helped make the economy more export-oriented. However, they primarily benefited low-tech sectors such as garments and textiles which did not require major new technological capabilities to compete in export markets. The support was phased out too quickly to enable producers in more complex industries to restructure and improve their competitive position.

The government has stimulated technology inflows and competition after 1983 through *liberalisation of FDI*. Cumulative FDI inflows reached almost US$ 6.2 billion by end-1990. However, by the end of the 1980s this boom had contributed little to technological modernisation in manufacturing. Most FDI flows went into services, especially banking, tourism and insurance. There are signs of change after 1990; the automotive sector in particular has attracted significant FDI, and it remains to be seen whether existing domestic manufacturers will cope successfully with the new competition.

S&T System

While it is only in the late 1980s, and even more so after 1990, that there was a serious attempt to draw up a comprehensive S&T plan, some important technology institutions had been set up before 1985. These included the Scientific and Technical Research Council of Turkey (TÜBITAK), which co-ordinates, organises and supports basic and applied research, and is the main body in charge of implementing S&T policy; the Higher Education Council (YÖK), which co-ordinates and regulates higher education institutions; and the Supreme Council for S&T (BTYK) which is the highest S&T policy making body in the government. S&T policy gained significant momentum only towards the end of the 1980s (from the Fifth Plan period, 1985-9, onwards). Financial incentives in the form of tax credits and exemptions for R&D were put in place and BTYK (which first convened in 1989) made proposals for building up the institutional infrastructure; these began to be implemented in 1990. After that several major new institutions were established, and began functioning in the first half of the 1990s, including the Turkish Patents Institute (TPE), the Academy of Sciences, the Metrology Institute (UME), the Small and Medium Industries Support Organisation (KOSGEB) and the Technology Development Foundation of Turkey (TTGV, a public-private joint venture set up with World Bank support to fund industrial R&D projects). In addition, a number of new universities were set up. The institutional infrastructure for S&T is now more or less in place, but there is little experience with S&T promotion, the majority of staff has little or no relevant skills, and linkages with industry remain underdeveloped (below).

The survey of S&T institutions studied these and related issues in detail. It covered TÜBITAK; four sector-specific research institutes affiliated to TÜBITAK, *viz.* the Marmara Research Centre (MAM), the Defence Industries Research and Development Institute (SAGE), the Information Technologies and Electronics Research Institute (BILTEN), and the Textile Institute (SAGEM), as well as KOSGEB, TPE, TTGV, and two private establishments delivering technical and/or managerial consulting services to industry (S&Q Mart and Management Consulting and Venturing, MCV). TPE has just started, and since it is a very specialised body it is too early to assess its activities adequately.

TÜBITAK continues to be the central agency in Turkey's S&T system. Its headquarters (employing 504 people out of a total of 1707 in 1997) has research grants committees, science fellowships committees, divisions for science and technology policy and technology assessment. In addition, it has units providing technology services and specialised affiliated research centres and institutes (among which are MAM, SAGE, BILTEN, SAGEM, UME and others). A reorientation of aims and priorities has been in the making since the late 1980s, emphasising stronger links with the other constituents of the NIS while consolidating its own lead role in that system, the improvement of the infrastructure for S&T information exchange, and more industrial research and pre-competitive development (mostly on contractual terms). The latter undoubtedly reflects the steadily decreasing share of public funding in its budget (currently 60 per cent). However, its expenditure has been increasing in real terms in the 1990s due to increased international transfers and revenue from payments for technology services.

A similar trend can be seen in the four sectoral research institutes functioning under TÜBITAK. MAM was modelled on the Dutch TNO, but evolved into an academic-oriented institution producing scientific papers with little relevance to industrial needs. Following an international audit in 1992, MAM has begun to restructure itself into an organisation for industrial contract research. A more commercial orientation is now regarded as essential, for its own viability (in the face of declining government support) and for its ability to make an effective contribution to industrial technology development. The main problems are industry's lack of R&D culture and the non-commercial orientation of its own staff. The trends and problems experienced by the other three sector-specific institutes are similar. They have made some headway in contract research, but in the case of SAGE and BILTEN the contracts are still mainly with public companies. They find it difficult to find commercial partners, partly due to the nature of the research that they carry out.

KOSGEB's objectives are to promote entrepreneurship, technology upgrading and competitiveness in SMEs, which play a very important role in Turkish industry. It has eight centres offering consulting and training services spread through the country. It also manages two technoparks (set up in 1991 and

1992) at the Technical University Istanbul (ITÜ) and the Middle East Technical University (METU), which function as business incubators. New entrepreneurs receive financial, equipment and technical support, and can stay on the estate for three years. According to KOSGEB, 65 schemes were funded, but so far only twelve entrepreneurs had left the (oldest) ITÜ estate; thus, the impact of the scheme is still fairly limited. Four more technoparks have been recently established, but are not yet functional. In relation to the vast numbers of SMEs in Turkey, KOSGEB has very limited outreach. However, this is not due to lack of financial support. In contrast to the organisations discussed above, the constraint appears to be lack of operating capacity rather than finance. Most of KOSGEB's funding comes from earmarked taxes and transfers, and income exceeds expenditure by a wide margin.

TTGV is an important organisation for industrial S&T. Its aims are to promote industrial R&D, encourage linkages between industry, higher education institutions and research institutes, identify priority research areas that will help close the international technology gap, and to help industry to use and commercialise scientific research output. It is funded by the World Bank and the Undersecretariat of Foreign Trade, and acts as a disbursing agent for the latter since government financial support for industrial R&D started (in 1995). It has committed US$ 43.3 million to 100 R&D projects so far, and industry has committed another US$ 50.9 million (at least 50 per cent of a project must be met by industry). The projects are predominantly in high-technology fields: materials technology, IT, machinery, electro-mechanicals and electronics, and biotechnology. The clients are Turkey's leading industrial firms. It does not reach the SME sector.

The success of the two commercial organisations, S&Q Mart and MCV, suggests that there are still significant gaps in the public S&T system. Private organisations can meet part of this need profitably. The case of S&Q Mart (a Danish-Turkish joint venture) is especially relevant, since it concentrates on technical consulting and training, in contrast to MCV which provides management support. S&Q Mart's main work is support with ISO 9000 certification, demand for which has grown spectacularly within the last few years. Other increasingly important activities are calibration, laboratory testing and technical inspection.

The problems faced by the S&T institutes vary according to their financial and legal status. The public institutes (especially sector-specific ones) emphasise bureaucratic procedures, low wages (about 30 to 90 per cent of the market average) which prevent the recruitment of better qualified staff, insufficient networking, inadequate promotion of services and insufficient funds. Clearly, the main problems are a hangover from the past when institutes functioned in isolation, networking was not required, and public funding was assured. Contacts and collaborations with other institutes for S&T development are still rather few. The transition towards more commercial operations finds much support in these institutes. It is expected that this will help reduce bureaucratic interference and facilitate the recruitment of qualified staff at better wages. However, the problem with human resources is partly caused by the inadequate supply of experienced scientists and engineers in the economy at large, which has not kept pace with demands from industry.

The privately owned S&Q Mart pays competitive salaries, but finding competent, committed and experienced people is its most important problem. Personnel lack experience with promotion of their services. Other problems, such as insufficient networking in the NIS or excessive bureaucracy, are not very important.

In addition to linkages among domestic institutions, international linkages could boost S&T significantly. Participation in EU programmes by Turkish S&T institutes could play a major role; however, as Turkey is not a full EU member it can participate in EU S&T programmes only if it pays its way (EU institutes are automatically entitled to financial support). TÜBITAK has had difficulty finding Turkish counterparts with the resources to join EU-sponsored R&D programmes. To a limited extent, the EU has been a source of funds for specific projects implemented by Turkish S&T institutes (for example KOSGEB's project for the creation of business and innovation centres and TPE's modernisation project). There is a strong demand for more involvement in EU industrial R&D programmes among the interviewed institutes.

Firm Level Analysis

The industrial sample consisted of ten textile firms, eight garment firms, four integrated textile and garment producers, six iron and steel plants (two integrated), and twelve automotive firms, of which ten were components and parts producers and two were producers of complete passenger vehicles. They varied greatly in terms of employment and turnover. The two integrated iron and steel plants and the two car producers were leading firms in the country employing thousands of workers each. Some textile and garment exporters were also quite large. In contrast, several of the automotive parts producers were small-scale industries, employing roughly between 20 and 50 workers and operating under family management. The great majority of firms were privately owned by local businessmen; a few had been recently converted into quoted companies. Private domestic ownership was dominant in the sample even before liberalisation, since the local private sector had played an important role during import substitution. Only three iron and steel firms had majority state ownership. There was foreign participation in three firms, all in the automotive sector.

The incentive structure for S&T development changed significantly after liberalisation in 1980, but it changed even more after the Customs Union agreement. Only four firms still receive export subsidies (long distance freight premiums), and import tariffs and quota now only apply to non-EU countries. Support from public S&T institutes after 1980 has been minimal. Only three firms acknowledged their existence, signalling the limited outreach of the S&T structure noted above. Preferential financing for export production is the only form of institutional support from which 18 firms still benefited in recent years. Twenty-two firms claimed that the extent of public support had decreased in recent years.

Import competition was felt to have increased (18 firms), particularly since the Customs Union agreement, by the textile and garments firms with substantial domestic markets, one integrated iron and steel producer and a leading car producer (which also faced increasing competition from foreign plants). However, several firms did not feel increasing import competition, and a few automotive parts producers gained domestic market share as a result of improved access to imported raw materials, parts and machinery. Increasing pressures to upgrade product quality was universal. Increased price competition was also mentioned by some, especially automotive parts producers. The financing environment improved for ten firms (due to improved accessibility of loans) but deteriorated for 16 others (due to the very high real interest rate, about 25 per cent). The outlook for expansion, and exports in particular, was mixed. For textiles and garment firms, the export boom is definitely over and they are struggling to keep their shares of markets which show signs of saturation and increasing competition from East Asia. Rising wages in the Istanbul area and the overvaluation of the Turkish lira in recent years have also affected their competitiveness. The iron and steel and automotive producers are more optimistic: for the former there are export possibilities (domestic demand has been erratic due to the volatility of the economy) while the latter benefits from new domestic demand from the new foreign car assembly plants.

In conclusion, the sample firms have been coping fairly well with increasing competitive pressures, despite the unstable macro-economic situation (high annual inflation of around 80-100 per cent). On average, their sales have grown by 5 to 10 per cent per year during 1990-5 (in US$ terms). There were no cases in the sample of a dramatic onslaught by foreign competition. However, at the time of the survey it was still too early to tell what long-term effects the Customs Union would have. The iron and steel, textile and garment industries had only just become exposed to the new trade regime, and the automotive sector will continue to receive protection for a few years more. The current patterns are still the result of partial liberalisation.

These changes have put pressure on the sample firms to increase their competitiveness through investment in technology, especially after the Customs Union agreement. The large majority have made considerable efforts to upgrade their technologies, and technological strategies have dominated financial expansion, efforts to improve marketing and various survival strategies such as hedging, wage suppression, moving into still protected sectors and lobbying. Foreign technology embodied in machinery and equipment has been the dominant source of technological improvement for 35 firms, domestic equipment suppliers playing a relatively minor role. Reverse engineering was significant in nine firms, but many firms did (mostly incremental) internal improvements, to adapt imported equipment to local conditions and to their specific requirements.

Recent investments in equipment have been substantial, on average US$ 85 million per firm in 1990-5. In the textile, iron and steel and automotive industries, investments were undertaken primarily for modernising machinery and equipment, but often also for capacity expansion – a sign of optimism about growth. All investments involved automation or computerisation. In the garment industry, by contrast, equipment investments have been more modest, with no cases of capacity expansion. The government introduced several investment facilities in the 1980s, which firms found quite useful: of the 39 companies in which some investment took place after 1990, 29 reported having benefited from at least one form of tax incentive or financing facility.

In addition to buying new technology, the sample firms undertook efforts to master, maintain, adapt and improve processes and/or products. However, the technological capabilities for undertaking such activities were fairly modest in the majority of sample firms, especially in SMEs, which have very limited resources and manpower for this purpose. Only 13 firms out of 40 had a separate R&D department, and the number of staff devoted to technological improvement tasks were limited. Many firms could not estimate their R&D expenditure; only the largest firms had separate R&D budgets. A lot of the technological effort took the form of shopfloor-based informal activities for cost-reduction, capacity expansion, workflow improvement, improvement of quality control and so on. Quality improvement assumed increasing importance, especially in the iron and steel and automotive companies, several of whom had recently been certified for ISO 9000 or were in an advanced stage of certification. In the textile and garment industries ISO 9000 was less important.

The main problems constraining internal technological efforts were as follows:

Financing: Public financing of R&D is still in its infancy (TTGV started in 1995) and excludes SMEs. The subsidies are disbursed *ex post* without correction for inflation. The requirement to formalise proposals for technological efforts under clearly defined R&D headings is also difficult for many firms (a problem that also occurs in relation to the tax incentives).

Lack of specialised personnel: There are serious shortages of supervisors, skilled technicians and designers in the labour market. The limited education of workers on the shop floor (few are educated beyond primary level) hampers the efficient absorption of new skills and techniques.

Lack of appropriate policy incentives for innovation: Aside from the tax incentives for equipment modernisation and the TTGV R&D financing scheme, which has started only recently, no concrete incentives for innovation appear to exist.

The absence of appropriate technology institutions: See below.

Most external technological contacts by private Turkish firms have been with *foreign* private agents. The iron and steel firms, and to a lesser extent the textile companies, collaborated mainly with machinery and equipment suppliers and consultants for design and installation work. The bigger garment companies had contacts with foreign designers, testing labs and consultants. Domestic *public agencies* had been more important for only one group in the sample, the automotive parts producers.

For the other firms, this category takes second place. Foreign public and domestic private institutions are of minor significance for the entire sample.

The interaction with the domestic public agencies has been heavily concentrated in a few organisations. The Technical University Istanbul was very popular (26 firms), and to a somewhat lesser extent the Marmara centre of TÜBITAK and the Technical University Ankara. There were also some instances of contacts with sectoral research institutes, mainly for testing, consulting and brainstorming; however, most of these were informal and/or transitory. There were hardly any instances of formal R&D collaborations. There has also been some contact with TPE and UME. KOSGEB has been used by six SMEs in the sample, mainly in connection with a training scheme for ISO 9000 certification, executed by S&Q Mart and sponsored by KOSGEB.

On the whole, the firms were dubious about the usefulness of these contacts. Only 25 per cent considered the support received to have been beneficial, while 50 per cent it to have been of little or no use. The largest problem was felt, particularly by SMEs, to be the high cost of services. Several auto components suppliers postponed ISO 9000 certification because the costs of certification were too high. Lack of understanding of problems of industry by the institutions was another frequently mentioned problem, mostly related to the lack of commercial orientation of the organisations rather than to their lack of technical expertise. Other problems were delays in service delivery, the lack of adequate equipment for testing and calibration, the limited outreach of institutions, and simply the non-existence of institutional support in a variety of areas.

Policy recommendations

(i) The Turkish S&T system has most relevant institutions in place; the main task is to strengthen them to provide more effective services. The most important needs are: setting up of technical service centres at the regional level, developing a viable model (or models) of technopoles, completing the establishment of primary and secondary metrology and calibration facilities, streamlining financial institutions supporting venture capital and R&D projects, establishing a system of data collection and evaluation for technology transactions and transfers are among the issues to be tackled. The complementary role of private sector science and technology providers, especially specialised consulting firms, should be recognised and encouraged. Public sector research establishments in the productive sphere must be restructured to increase their capability to serve private industry.

(ii) More resources must be allocated to informal technological effort as well as formal R&D. The government should recognise the crucial role played by activities of the engineering and production departments in design, retooling, outsourcing of technical services, standardisation, etc. in addition to formal R&D. These will gather momentum with increasing complexity and productivity of Turkish industry; hence concentrating on raising R&D narrowly defined is inappropriate. For example, the accounting requirements to qualify for tax relief or subsidies for technological development should be broadened, so that expenditures such as consultancy fees for ISO 9000, manpower training and fees for the use of testing labs (to mention a few possibilities) could be eligible even though they are not part of a formal R&D project. There is a need for financial support for programmes of applied research and technology upgrading in SMEs, which may be implemented in collaboration with sectoral industry associations and private research institutes. There is also scope for more initiatives along the lines of the KOSGEB-sponsored ISO 9000 training scheme. There is valuable expertise in the private consultancy sector which can be used to assist technology development in SMEs. However, it would be unrealistic to expect KOSGEB to serve a large proportion of the ‘micro’ establishments in Turkey. SMEs are numerous, have a high incidence of entry and exit, and many of them are technologically not very demanding; smaller, more localised, support institutions would be more appropriate to meet their needs.

(iii) Existing S&T institutions must establish stronger links with industry and with each other. It is important to make top-level decision making more effective and influential in setting priorities, strengthen technology assessment units in TÜBITAK and Ministries of Industry, Agriculture and Defence, selectively upgrade higher education establishments with a greater degree of co-operation and division of labour among them, and support collaborative research with private industry.

(iv) It is vital to expand and upgrade educational facilities to meet evolving skill needs, especially in branches of engineering, information technology and textile design.

The contribution of the EU to these tasks will crucially depend on whether Turkey can effectively participate in the preparation of the EU R&D policy-making and R&D programmes. Until such time as this participation can take place, Turkey is likely to conceive of the EU as (i) the main source of scientific and technological expertise, (ii) a role model for institution building, rule formulation and policy setting on S&T issues, and (iii) an important source of funds for improving the S&T infrastructure. This falls short of full co-operation, but this is what seems feasible at present.

Mexico

Mario Cimoli

This study analyses the links between Mexican S&T policies and its industrial development, with particular attention to the role of institutions and policies. In order to interpret the results, account is taken of the macroeconomic setting and the main changes in the regulatory framework through the three Mexican development phases: the ISI (import substitution industrialisation) period, the new macroeconomic setting, and the recent liberalisation, stabilisation and NAFTA. The last section presents a taxonomy of sectoral learning and their interplay with S&T policies and institutions.

The ISI Period

Trade protection, credit and fiscal policies provided a favourable environment for the development of Mexican industry in the first stages of ISI, yielding high rates of GDP growth. A long period of stable exchange rates, price control in key sectors and small budget deficits favoured national and foreign investment flows towards this sector. The ISI model – common in Latin America and other developing regions – had strong protection coupled with easy entry of foreign technology (mainly via foreign direct investment, and not fully diffused through the system). The industrial sector had national private firms producing consumer and intermediate goods, together with public enterprises in infrastructure and MNCs in more advanced industrial activities. This incentive structure diverted resources from traditional exporting activities. The manufacturing sector, though improving its external performance over the 1950's, registered increasing trade deficits, so undermining its sustainability (a tendency worsened by growing federal deficits).

While import substitution can provide a tool to develop 'infant' industries, in Mexico the strategy was characterised by a continuous *hampering* of technological learning. The failure to implement selective policies prevented Mexican industry from realising economies of scale and generating and exploiting network externalities. Learning was largely confined to efforts to adapt embodied foreign technology: imported machinery dominated industrial investment from the first stages of ISI, when most activities were labour intensive (as textiles and food). This pattern continued in the 1960's, when MNCs set up in automobiles, components, electronics etc., and in the 1970's, when efforts were made to promote resource-intensive activities (in particular petrochemicals). An unfavourable environment for *R&D* (its high costs, absence of public support etc.) confined it to a few sectors dominated by oligopolistic firms that exploited protection to increase production capacity (as in glass and brewing).

The incentives for importing technology prevented many Mexican manufacturing activities from moving from adaptation and minor improvements into more advanced innovative capabilities. The result was that the industrial structure built under ISI was not able to generate technology or diffuse it across sectors. In a world with rapidly changing technologies, many Mexican technologies fell behind international frontiers. Three factors shaped learning in this phase: concentration of efforts by 'specialised supplier' and scale-intensive sectors on organisational innovation, with low economies of scale; predominance of the discontinuous over the continuous mode of production within family firms and subsidiaries of MNCs; and a high degree of vertical integration in firms, with under-developed local supplier and subcontractor networks.

Formal S&T policy started only in the 1970s, when policies were launched to foster domestic technological capabilities, with the primary aim of reducing technological dependence. In order to regulate technology flows, a set of laws were promoted on foreign investment and on technology transfer in 1973 and on industrial property in 1976. The National Council for Science and Technology (CONACYT) was founded to promote national research and technological development and create national scientific and technological capabilities by developing human resources. In this period the state was the main promoter and sponsor of R&D, largely undertaken in universities and public centres. The private sector conducted little R&D and financed practically none of the research conducted in the public institutions.

The first National Plan for Science and Technology (1976) included both instruments encouraging S&T upgrading within industry (protection of industrial property rights through patents, institutions for the diffusion of information related to new technologies, fiscal reductions for investments in technological upgrading, creation of a system of technical standards and regulations) and direct promotion (tariff protection, production planning, fiscal incentives, provision of loans to enterprises and of training for their employees). As a result, S&T expenditure grew steadily during these years, with the Government playing a major role. During 1977-81, massive investments were undertaken to exploit oil fields. S&T expenditure reached its peak, but the inflow of foreign technology was also at its highest, with imports of machinery growing at an average annual rate of 33.1%. The consequence of such large imports of technology was a slowing down of internal S&T activity.

The educational system in those years did not provide the resources needed for sustained development. The completion rate in 78/79 was 56.1% for primary school, 70.2% for junior high school, and 64.8% for senior school. The importance of the educational system for technological development cannot be over-stressed.

The Macroeconomic Adjustment Period

Starting in 1976 major shifts in many macro-economic indicators (exchange and interest rates, public deficit) were accompanied by the attempt to change the path of development, with a move away from ISI. This produced confused incentives as far as industrial policy was concerned, particularly in the second half of the 1980's. The adjustment following the 1982 debt crisis occurred through domestic demand contraction and large devaluations. These helped the trade balance, particularly for highly price sensitive exported commodities (as chemicals, food and textiles). Low rates of growth and disinvestment (reflected in falling growth rates of net capital stock as well as gross capital formation) affected the ability of the manufacturing sector to increase its efficiency and productivity. The exposure to import competition differed by activity; some (like chemicals and automobiles) that were exposed more gradually were able to turn to the world market in the mid-1980s. The performance of the automobile sector was, in particular, influenced by foreign investments in the late 1970s, attracted by a special regime for imports and exports; the chemical sector benefited in the same period from strong incentives such as protection, subsidised inputs, export incentives, and so on.

The industrial policy measures announced in this period seemed to conflict with the trend towards liberalisation. Thus, the new Industrial Plan (1984-88) stated that industrial development continue with protection combined with export incentives as in the previous decade. However, trade liberalisation continued, and protection was reduced *de facto* . The 'opening up' took the form of first replacing import licenses (the most significant trade barrier) with tariffs, to keep effective protection constant; and later reducing the average level of tariffs. In the first stage (1982-85) liberalisation was quite slow, the average level of tariffs increased (to maintain the high levels of protection granted by quantitative restrictions), as did official import prices. The portion of tariff items subject to licence requirements fell rapidly from 100% in 1983 to 10% in 1985. Trade policy was made more transparent, by simplifying tariff schedules and reducing the number and dispersion of tariffs rates. Mexico acceded to the GATT in 1986, adopting the Harmonised Commodity Description and Coding System, the Foreign Trade Law and the Antidumping Code. It abolished price controls and accelerated tariffs reduction and rationalisation. It began to lift restrictions on foreign ownership by simplifying regulations (FDI had fallen dramatically during the crisis).

From 1983 there was a change in S&T policy. S&T expenditure, which had increased steadily over 1970-80, started to show both large fluctuations and falls in line with macro adjustments: the ratio of S&T expenditures to GDP fell from 0.43 to 0.30 over the decade. The composition of S&T expenditures in terms of public and private sources also changed. During this period, public expenditure (the dominant portion) fell sharply as a result of adjustment, but S&T expenditure suffered even larger reductions, so that the reduction in the ratio of S&T to public expenditure was 5 percentage points larger than that in the ratio to GDP. The government share of R&D was eight times that of the industry and about twice the average of that of a sample of industrialised countries.

The Mexican R&D system is composed of public sectoral R&D and SEP centres, the public education system (in particular the universities, which receive over 30% of federal funds allocated to S&T), R&D centres of business enterprises (national and multinationals) and non-profit institutions. The lion's share of expenditure comes from public institutions, especially the universities located in Mexico D.F.

Mexico's stock of human capital is relatively small, and considered inadequate for the technological capabilities needed to raise its international competitiveness. Mexico ranks well among the other newly industrialising countries in terms of primary enrolments and vocational education, but is low in terms of secondary, tertiary and vocational enrolments, and the number of tertiary level students in science related fields and in engineering. The number of scientists and engineers engaged in R&D is also relatively low. A renewed effort was therefore recognised as necessary in order to develop a larger base of human capital.

Another issue dealt with in the new S&T policy was industrial property rights. In the ISI period the regime was protective of domestic property rights but not foreign ones. In the new regime foreign firms were given equal protection. The new policy also put the private sector at the centre of S&T. The accent was shifted from the development of internal scientific and technological capabilities (to reduce dependence on inflows of foreign technology) to developing S&T capability for assimilating and diffusing foreign technology. This entailed deregulation and enhancement of the private sector's competitiveness through increased efficiency and assimilation of foreign technology.

The New Economic Policy, Liberalisation & NAFTA

The new economic policy after 1988 led to decreasing inflation, huge foreign capital inflows, initial GDP growth and progressive appreciation of the real exchange rate. Within the new setting an expansion of internal absorption contributed to an unfavourable relative price environment (prices of non-tradables increased relative to that of tradables) and to increasing imports, causing growing trade deficits. The incentives generated by the new macroeconomic setting penalised the tradable sector, demonstrated by the shift of FDI to services (financial services, communication and transportation) and their growing share of total net capital stock .

In 1988-92, manufacturing growth averaged 3.7%, and the sector had increases in both labour and capital productivity, though growth rates of employment and net capital stock decreased. In this phase, manufactures accounted for the bulk of the trade deficit, amounting to US$ 83.8 billions. As in other Latin American countries, manufacturing reduced its level of vertical integration and increased its import content, with the fastest growing activities accounting for the highest (84.4%) import coefficients. Exports continued to grow, but at lower rates (5.8%) than before (24.2%).

Structural change in manufacturing was heterogeneous. There was a growing importance of automobiles and chemicals, with traditional manufactures like textiles, metal products, machines and wood losing importance. The groups with the highest growth and best export performance (accounting for 41% of manufactured exports) in 1988-92 were MNCs (automobiles, electrical equipment), state monopolies (basic petrochemicals) or private national oligopolies (glass and beer). The industries that coped best with the new environment were the ones that had accumulated substantial capabilities during the ISI phase. Most were able to increase their productivity because of a modernisation process that started in the late 1970’s, as a consequence of public incentives (chemicals) or MNC strategies (automobiles). Moreover, liberalisation of imports, decreasing vertical integration and the development a network of external subcontractors (auto, electronics) allowed them to substitute local inputs and services with foreign produced ones, reducing the impact of the real exchange rate overvaluation.

These tendencies reduced local content as well as the share of local firms in output (as in textiles, auto and electronics). This held back inter-industry technology flows and provided an unfavourable environment for innovation and learning. The development of technology was driven mainly by inflows of foreign knowledge, with firm-level efforts focused on improving productivity and product quality. Imports of capital goods, which had become more attractive because of changes in relative prices, were the main source of new embodied technology, and in most sectors firms concentrated on improving training and organisational efficiency rather than deeper technological efforts, such as R&D and production engineering.

The S&T system was also restructured. From 1992, responsibility for S&T policy shifted from the Secretariat of Programming and Budget to the Secretariat of Public Education (SEP). SEP undertook the co-ordination and the promotion of national S&T development, and, advised by CONACYT, formulated the National Programme for Scientific and Technological Modernisation (PRONCYMT). CONACYT became the executive and consultative body. Its duties entailed the organisation of S&T activities with the Federal Executive, and the co-ordination of the national and foreign institutions involved in the implementation of such policies. The powers conferred on CONACYT were wide-ranging, and this body has to be consulted on all matters concerning scientific and technological development.

There exist, however, considerable restrictions on CONACYT’s authority, as several ministries autonomously carry out their own S&T activities. More importantly, financial responsibility for S&T remains under the Ministry of Finance. A Planning Committee, including representatives of all the bodies involved in S&T policy, was not effective; it lacked control over the financial resources for S&T in the budget, and has not operated since 1991. Partly to overcome this problem, a National Co-ordinating Committee for Technological Modernisation (CONCERTEC) was established in 1992. It was intended to foster linkages between R&D and business enterprises, co-ordinate the public bodies involved in S&T and develop financing for the technological upgrading of industry, with particular attention to the needs of SMEs.

This period also saw considerable institutional strengthening to promote S&T. In basic S&T infrastructure, three important institutions set up recently (1993-94) are:

- Mexican Society for Standards and Certification (NORMEX), concerned with standardisation, patents and trade-marks, and quality certification.

- Mexican Institute of Industrial Property (IMPI), administering property rights, stimulating technological upgrading and technology transfer.

- National Metrology Centre (CENAM), responsible for legal metrology.

The financing of technological upgrading is being promoted by:

- FIDETEC (credit for investment in modernisation and innovation projects), covering 100% of the cost in the case of SMEs and 70% for large enterprises.

- FORCCYTEC (credit to the setting up of private R&D centres which offer their services to the national industry), covering 50% of the costs with CONACYT finance.

New institutions for the diffusion of information on technology, standards and quality are:

- Unit for Technology Transfer (UTT), providing information and advice on technological assimilation and technology transfer to enterprises which undertake modernisation.

- IMNC, offering services related to standards and quality.

Programmes to promote linkages between R&D centres and industry include:

- Programme of Linkages between Academia and Enterprises (PREAEM), promoting and subsidising strategic alliances for technological upgrading between public R&D centres and private enterprises.

- Programme of Technology Incubators (PIEBT), financing technology incubators by collective initiatives to develop science and technology intensive activities.

SME needs are not being adequately met by existing institutions and programmes, but there are signs of improvement. The greatest gaps are in developing innovative capabilities and negotiation for technology acquisition. Limited access to credit and supporting services is damaging SMEs that mostly produce for internal markets and suffer large variations in production and sales during the period of modernisation. Our interviews suggest that FIDETEC has had a very limited impact on industry. The FORCCYTEC programme has had limited effects in the first two years of its creation, but lately it has financed a number of centres supporting SMEs. PREAEM is having a positive effect on SMEs, which are being linked to educational institutions performing research in related areas. The programme of technological incubators has been judged the least effective, with very modest results.

Relationships of S&T Policies/Institutions with Sectoral Learning

The sectoral analysis and surveys of different types of firms leads to a taxonomy of sectoral learning and its interplay with macro and S&T policies and institutions (see annex tables). There are various sectoral differences and learning patterns, summarised below.

1. Macro and trade policies, as well as the regulatory framework introduced by NAFTA, have had a strong influence on learning in each sector. While learning has taken place over all the different phases of industrial development in Mexico, a large number of firms in different sectors have disappeared. Mexican industry displays dynamic comparative advantage only where efforts have been made in process innovation, increasing learning capabilities (improving organisational

efficiency and skills, absorbing foreign technology) and improving production organisation. This processes can be explained by the need to compete in international markets.

2. This learning process has, however, occurred mostly within firms, with little interaction with institutions or with prevailing S&T policies. That is, learning and innovation have responded mainly to market signals, not to top-down S&T policies. This suggests that S&T policies were not properly articulated or co-ordinated, and lacked clear incentives for technological activity by industry. Liberalisation led firms across sectors to increase their efforts to raise productivity and quality; for instance, in chemicals, brewing and glass, R&D activities were re-oriented to quality, cost reduction, standardisation and utilisation of imported machinery and equipment.

3. Learning was dominated by MNC affiliates and large domestic firms. However, their patterns of learning differed. MNCs benefited from strong incentives to set up production facilities in Mexico, initially from trade policy and, more recently, from the NAFTA agreement (the latter is also a powerful magnet for firms from outside the North American region). They maintained strong links with their parent companies with respect to technology flows; their learning mainly consisting of adapting capital goods, increasing production capacity and improving process efficiency and quality standards. They also made efforts to increase inter-firm linkages (producer/user) and personnel training, with clear distinction between MNCs whose production involved local material inputs and the *maquiladora* industry, which was primarily interested in low cost labour. One crucial difference between them was the use of high-level technical manpower: the former used a great deal of such manpower in sectors such as the automobile industry, whereas the *maquiladora* industry uses much less specialised local human capital. Learning in large domestic firms was based on their efforts in the import-substitution phase, when they developed design and engineering capabilities, improved organisational methods and increased production capacity. For example, large groups in the chemical, brewery and glass container sectors developed such capabilities and developed R&D to support their knowledge base. In this period, these firms also developed the necessary scale economies that allowed them later to compete in international markets.

4. There are two distinct patterns in the *textile* and *footwear* sectors. In the former, joint ventures and *maquila* firms are gaining importance, which compete increasingly in international markets. Their learning involves training, just-in-time production and better marketing.. In contrast, traditional family firms are characterised by inefficient organisation. Their efforts concentrate on increasing economies of scale and organisational efficiency to serve domestic markets. In the footwear sector, regional technology policies and institutions have supported firms in terms of improving quality and greater integration within the sector (in industrial districts).

5. S&T policies and institutions have also changed across the different phases. From the import-substitution phase to the most recent period, human resources have been improved and expanded continuously. Several instruments have been used, including scholarships and public financing. In addition, public technology projects have incorporated shared risk schemes. Different types of institutions have been created: in the first period supply-side institutions predominated, while after liberalisation institutions are required to satisfy industry needs for quality, standardisation and certification. There is the recent appearance of a few ‘bridge’ institutions to strengthen linkages between the firms and the public S&T structure. There is thus a dichotomy. On the one hand, firms pursue their learning efforts with weak linkages with institutions and little direct response to S&T policies, while, on the other, institutions do not have strong incentives to promote linkages with industry and carry on with little connection with industrial needs.

Annex: Taxonomy of sectoral learning and their interplay with S&T policies and institutions

SECTORS AND THEIR CHARACTERISTICS			**IMPORT SUBSTITUTION**		**TRANSITION** **1982-87**	**NEW REGULATORY FRAMEWORK (AFTER 1988) & NAFTA**
	TYPE OF SECTOR	TYPE OF FIRM	SECTORAL CHARACTERISTICS (size, openness etc.)	TECHNICAL CHANGE IN CLOSED ECONOMY AND TYPE OF LEARNING	TRANSFORMATION AFTER THE CRISIS New Macropolicy and Regulatory framework	TYPE OF LEARNING: Learning effort and influence of S&T system
Automotive	Scale Intensive	MNCs (from Japan, USA and Germany) and some local initiatives	Highly protected sector Oriented to the domestic Market Large assembly plants Localised in the centre of the country	Adaptation of plants and blueprints Adaptation of design and products to the local market Efforts to improve organisation of production. Increasing capacity to obtain full production (effort to increase economies of scale). Low quality standard (producer-user in term of quantity and prices only).	Increase in the number of firms Higher participation in the international market (increasing exports into the NAFTA area). More international integration (decrease in the linkages with local firms). Decrease in the number of domestic producers of parts (lower linkages with domestic firms). A change in the geographical distribution of firms. Protected sector. Competitive advantage based on static resource endowments (low labour cost).	Some tentative of local R&D Increasing production capacity and improving organisational efficiency process innovation product quality (increasing economies of scale). Increasing inter- firms learning effort (producer-user interplay based on quality, large participation of multinational producer of autoparts). Training: effort (increased effort to obtain technical skills of the personnel at the floor shop).

Chemicals	Scale Intensive & Science based	Locally owned firms (big, medium and small firms)	Oriented to the domestic Market Increasing production capacity Highly protected sector and national monopoly (PEMEX)	Adaptation of plants and blueprints. Strong engineering national capabilities. Training: effort (increased effort to obtain technical skills of the personnel at the floor shop).	Higher participation in the international market (increasing exports). Increasing intra-sectoral trade. Increasing capital concentration. Increasing of raw material prices produced by PEMEX.	Increasing R&D oriented on production efficiency for the firms export oriented (quality , cost reduction, utilisation of acquired machinery and equipment). Training: effort (increased effort to obtain technical skills of the personnel at the floor shop).

A taxonomy of sectoral learning and their interplay with S&T policies and institutions

SECTORS AND THEIR CHARACTERISTICS	IMPORT SUBSTITUTION	TRANSITION 1982-87	NEW REGULATORY FRAMEWORK (AFTER 1988) & NAFTA

	TYPE OF SECTOR	TYPE OF FIRM	SECTOR'S CHARACTERISTICS (dimension, openness, etc.)	TECHNICAL CHANGE IN THE CLOSED ECONOMY AND TYPE OF LEARNING	TRANSFORMATION AFTER THE CRISIS New Macropolicy and Regulatory framework	TYPE OF LEARNING: Learning effort and influence of S&T system
Brewing	Supplier Dominated and Scale intensive	Locally-owned firms (duopolistic market)	Oriented to the domestic market. Increasing production Capacity. High control of the domestic market through distribution channels (small shops and low cost returnable bottles).	Adaptation of imported capital goods and plants and effort to improve production process. In-house R&D primarily oriented to generate local Knowledge (experimentation with new material and process of production). Taking part in conferences. Literature reviews, Interaction with foreign breweries . Training, hiring foreign technicians, engaging technicians on a temporary basis to solve technical problems).	Higher participation in the international market (increasing exports). Increasing economies of scale . Participation in financial institutions.	R&D oriented on production efficiency (quality , cost reduction, utilisation of acquired machinery and equipment). Reduction of the attendance to conferences and literature reviews. Increased interest in the publications of equipment suppliers. Internal and external benchmarking (benchmarking of effectiveness between plants and diffusion of the best internal practices within the firm). Use of mergers as a mechanism for learning from world players. Investment in equipment. Training: effort (increased effort to obtain technical skills of the personnel at the floor shop).
Glass container	Scale Intensive	Locally-owned firms (oligopolistic market)	Oriented to the domestic market. Increasing production Capacity.	R & D (both the activities of research and development were important). Literature review, patents and information search. Meetings to analyse experiences. Hiring experienced personal from outside, personal training.	Higher participation in the international market Increasing economies of scale.	R&D oriented on production efficiency (quality , cost reduction, utilisation of acquired machinery and equipment). External benchmarking.

			Low cost returnable bottles use in beer and other soft drinks (possibilities economies of scale).	Joint ventures and making visits to competitors' facilities. Manufacturing glass containers and equipment. Reverse engineering.	Participation in financial institutions.	Acquiring firms. Investment in equipment and reverse engineering. Training: effort (increased effort to obtain technical skills of the personnel at the floor shop).

SECTORS AND THEIR CHARACTERISTICS			**IMPORT SUBSTITUTION**		**TRANSITION** **1982-87**	**NEW REGULATORY FRAMEWORK (AFTER 1988) & NAFTA**
	TYPE OF SECTOR	TYPE OF FIRM	SECTOR'S CHARACTERISTICS (dimension, openness, etc.)	TECHNICAL CHANGE IN THE CLOSED ECONOMY AND TYPE OF LEARNING	TRANSFORMATION AFTER THE CRISIS New Macropolicy and Regulatory framework	TYPE OF LEARNING: Learning effort and influence of S&T system
Consumer **Electronics** **(TV sector)**	Scale Intensive	MNCs (from Japan, USA and Europe)	Highly protected sector. Large assembly plants. Localised in the centre of the country. Oriented to the domestic Market.	Low R&D.	Increase in the number of firms. More international integration (decrease in the linkages with local firms). A change in the geographical distribution of firms (more firms along the frontier with the USA: Tijuana and Sonora). Inputs are produced outside the country and firms belong to international intra- firm	Effort to improve production efficiencies (quality , cost reduction and improvement in the organisation of production). Qualified technician from the EEUU and Japan. Training: effort (increased effort to obtain technical skills of the personnel at the floor shop).

					networks. Competitive advantage based on static resource endowments (low labour cost).	
Textiles	Supplier Dominated Labour intensive	Locally-owned firms	Highly protected sector and large contribution to GDP. High employment share in the local industry and small production scale. Oriented to the domestic Market.	Adaptation of imported capital goods. Adaptation of plants and production organisation. Pirated design. Tentative linkages with local producers of machinery and equipment.	High impact of macro-crisis. Diminution of sectoral investment. Reduction of sectoral employment and number local firms in the sector. Family control of the firms and moderate increase of maquila and joint ventures. Increasing imports of machinery and equipment (domestic provision disappears). Competitive advantage based on static resource endowments (low labour cost).	Joint ventures and foreign firms increase their efforts on quality control, just in time and commercialisation. In family firms inefficient organisation and administration (effort to increase economies of scale and organisational efficiency). Pirated designs and imitation (designing, printing and dyeing). Training: effort (increased effort to obtain technical skills of the personnel at the floor shop).
Footwear	Supplier Dominated	Locally-owned firms (small and medium firms)	Oriented to the domestic market.	Technological background of entrepreneur and personnel, local tradition. Based on imported capital goods (investment in imported machinery and equipment) and adaptation of plants.	Higher participation in the international market (low labour cost and dumping practice). Effort to vertical and horizontal integration. High labour mobility. High concentration in Leon with an industrial district structure (micro, small and medium firms).	High institutional support from specific institution and local technology policy. Effort in a programme of quality. Based imported capital goods (investment in imported machinery and equipment) and adaptation of plants.

				Creation of a centre (CIATEC) for technological support in the area.		Design imitation.

Taxonomy of sectoral learning and interplay with S&T policies and institutions

	IMPORT SUBSTITUTION	TRANSITION 1982-87	NEW REGULATORY FRAMEWORK (AFTER 1988) & NAFTA
General context	Learning based on the adapting imported technology embodied into capital goods and reverse engineering. High R&D cost and reduced and isolated R&D activities (oriented to produce long term knowledge). Lack of transmission of technological information. Efforts to introduce in the scale sectors continuos production processes, increase the size of the plants and increase economies of scale. Weakens in the international competitiveness: reduced quality and capacity for standard certification. Increasing inter and intra sectoral vertical integration.	Increasing international competitiveness. High firm mortality and lower presence of the specialised supplier sector. Diminution of vertical inter and intra sectoral linkages. Little use of the available public resources and their diminution.	Industrial structure and learning process dominated by the strategies of multinationals and local large firms. Low R&D and high efforts oriented to improve production processes, quality and economies of scale (learning process oriented to increase productivity: cost reduction, utilisation of acquired machinery and equipment)). Increasing demand and adaptation of foreign technology oriented to obtaining higher competitiveness. Efforts to obtain quality and increasing capability to adopt international standards and certification. External benchmarking. Difficulties for the local small and medium firms to obtain foreign technology. Training: effort (increased effort to obtain technical skills of the personnel at the floor shop).

Institutional actors	Several public institutions contribute to the formulation of S&T policies: Ministry of Finance, Ministry of Industry, Ministry of Education, National Council for Science and Technology (CONACYT) and other decentralised institutions. Absence of mediators and linkages across the different bodies.	Lack of co-ordination between instruments, agents and services for technological development. Most of S&T policies falls under the supervision of CONACYT. Emergence of decentralised agents providing linkages across the existing actors.	A non co-ordinated system appear, characterised by: CONACYT which acquires the status of central organisation to the promotion of S&T polices the emerging of bridging public and private institutions oriented to certification, quality standards and personnel training. The Coexistence of different organisation to support R&D at the national and regional level, to provide incentives and to provide information for standardisation, certification, quality and training.
General objectives of S&T policies and instruments	Increase the infrastructure for technological support. Effort to increase and improve human resources. Programs of financial support to innovation projects. Scholarships for scientist and technicians. Public financing through *fidecommesso.* Direct credits.	Continuation of the preceding policies plus: Creation of an infrastructure an services for metrology and certification. Effort to increase the participation of private agents in technological upgrade. Effort to stimulate technological modernisation of firms. Funds for high risk projects. Deregulation to stimulate private financing.	Continuation of the preceding policies plus: Funds for high risk projects (and shred risk projects). Regional financing.
Overall policy features	Offering public services. No quality evaluation of results. Bureaucratic procedures and selection process. Double-dealing in the functions and instrument of the different public organisations.	Offering public services. No quality evaluation of results. Lack of organisational co-ordination. Stimulation the participation of private agents. Stimulation of linkages between University and firms.	Certain quality evaluation mechanisms are introduced. Search for simplifying procedures. Co-operation between public and private agents. Stimulation of inter-firm co-operation. Elimination of some inefficient programmes. Search for profitable projects.

Policy Implications

Sanjaya Lall

Introduction and Reprise

The analysis of S&T policies and institutions in these four countries confirms many of the findings of the literature survey. The extent and effectiveness of technological effort responds to a range of different incentives, in particular changes in trade regimes and macroeconomic problems. Each of these countries went through difficult macro circumstances and massive changes in import regimes: there was a radical change of economic and political systems in Hungary, with rapid opening up in very difficult economic circumstances; more gradual liberalisation in Turkey leading up to a customs union with the EU; rapid liberalisation in Mexico after a massive macroeconomic crisis, followed by partial integration with the USA; and complete integration with the EU in Greece. Turbulence in the macroeconomic environment affected the ability and willingness of industry to invest in long-term technology upgrading. Each started with a different base of industrial skills and institutional base in S&T: Hungary was the most advanced, with a long tradition of complex industrial production and R&D, Greece the least, with a predominance of simple labour and resource based manufacturing activities. Mexico had a diverse industrial structure but with most advanced activities under the aegis of MNCs engaged in production but little technological activity, Turkey with large domestic private and state enterprises in a range of activities but with a weak presence in technologically advanced activities.

In all cases, liberalisation has forced enterprises to upgrade their technology, by importing new equipment, seeking FDI or joint ventures, improving production, quality management and organisational techniques, and investing more in absorbing the new technologies. The speed of liberalisation and the accumulated base of capabilities have been critical determinants of the effectiveness of the technological response: very rapid opening up combined with weak capabilities has led to a poor response, while more gradual opening with strong learning bases has led to more positive and significant upgrading. A strong involvement of MNCs in the restructuring process has led to the rapid transfer of state-of-the-art technology but to little technological deepening. Rapid liberalisation has generally resulted in a regression of export patterns to static bases of comparative advantage, primarily cheap semi-skilled labour; this is particularly marked in Greece and Turkey. However, there are exceptions where strong capabilities exist (often under past import substitution), as with engineering in Hungary (but many firms have had to go down the technology ladder in order to survive), automobiles and chemicals in Mexico, or iron and steel in Turkey.

Much of the technological activity undertaken in response to liberalisation comprised ‘minor’ innovation (efforts to master, adapt and improve upon imported knowledge) rather than innovation at world frontiers. The bulk of technology activity in developing countries is of this nature, but in some cases export orientation with a large base of technical skills and careful industrial promotion has led (as in the larger East Asian NIEs) to considerable deepening of technological activity: this is rarely found in the sample countries. On the contrary, rapid exposure to international competition has induced firms to resort to less risky or long-term strategies of importing technology, embodied and disembodied. In complex technologies, this has also led, as in Mexico, to lower degrees of local content and so reduced internal diffusion of technology. However, it is possible that the ‘first stage’ response of upgrading manufacturing productivity, raising quality levels and introducing modern management practices will lead to deeper technological activity: and here support from the S&T infrastructure may be of critical importance. The ‘first stage’ response itself does not call for much interaction with S&T institutions with the exception of those that diffuse technology and help with minor quality and troubleshooting problems. It does call for extensive financial and extension support for SMEs, something in which all the countries are deficient.

There are differences between the S&T systems of the four countries, varying by industrial maturity and past traditions of technological activity. Hungary has the most advanced S&T infrastructure of the four countries, with a large number of specialised institutions and also a long tradition of in-house R&D by industrial enterprises as well as collaboration with research institutes. In fact, the extent and effectiveness of firm-institution interaction depends crucially on the ability of firms to undertake in-house technological activity: only then can they perceive the need for external assistance, frame the problems they need solved, approach the appropriate provider of information, services or research, and absorb the results effectively. One of the basic reasons for low interaction between the S&T system and industry in many countries is the low level of capabilities on the part of firms, with a vicious circle in which research institutions develop in isolation, have similarly low capabilities and fail to establish credibility with the private sector. The other three countries have recently set up a broad range of S&T institutions, in particular Mexico, followed by Turkey and Greece. The effectiveness of these is limited by the lack of a tradition of industrial R&D by firms.

The impact of liberalisation and (actual or potential) economic integration has also differed. The S&T structure in Hungary is being downgraded as a result of the speed and extent of systemic changes, economic stringency and the lack of an appropriate strategy. Many research institutions have been thrown on the market without adequate preparation or access to the resources they need to make the transition, with the result that many have expired while surviving ones have had to substitute research with more mundane technical services. Some of this change is clearly desirable, bringing the institutions more in line with industrial needs, but some is not, since it erodes the research base which allows the institutes to provide effective support. In contrast, the other countries are strengthening their S&T bases, in particular Turkey and Mexico, and are adopting many measures to intensify their linkages with firms (there is also one notable effort in Hungary to increase linkages) but with few results evident so far.

In the final analysis, it must be admitted that the S&T institutions in the four countries have played a minor role so far in supporting the technological upgrading of industrial firms. Where strong incentives exist for co-operation, as in Greece, some linkages are found but are likely to be evanescent. Most firms regard the institutions with indifference or suspicion, and the most common complaints have to do with the high cost of services, lack of understanding of each others' problems and priorities, and basic 'cultural' differences with respect to confidentiality (firms want secrecy while researchers want to publish) or time (firms have tight deadlines, researchers do not).

Policy Implications

The stimulation of S&T involves a large number of factors, from macro management and trade strategy to human resource development and S&T policies in the narrower sense. This study could not cover all the broader factors in any detail, though the country case studies noted the importance of the macro environment, a competitive spur to firms (tempered by a cushion for learning complex technologies) and the critical role of the human resource base. The main focus was S&T policies in the narrow sense.

Let us start with policies that *the governments themselves can adopt*. The main policy implications that emerge from the studies are:

- The most important determinant of S&T success is the *industrial firm's own investments* in technological activity, not the infrastructure institutions *per se*. Without technological dynamism in firms that creates a demand for technological assistance, S&T institutions cannot 'push' their output to the industrial sector. This is especially so for more advanced forms of technological activity, such as design and innovation, are concerned. It applies less to more routine services such as testing, certification, troubleshooting, quality upgrading and so on, for which there is growing demand with the progress of liberalisation; however, even here there is a need for firms to be better aware of their technological shortcomings (by international standards) and what they need in terms of external assistance; in less developed countries, liberalisation often results in the extinction of firms that are unable to even define their technological needs. The first step of S&T policy must be to stimulate technological activity within firms in all its forms, from shopfloor productivity raising to formal R&D. This can be done in many ways, but it is not easy to create a 'technology culture' where none exists. The most common tools – assuming that the incentive regime is appropriate – are R&D tax incentives, grants/loans for technological activity (most effective in a cost sharing form), co-ordination of different firms in pre-competitive research, and a concerted campaign at raising awareness of the need for technological activity (best done jointly with industry associations). In general, fiscal incentives (beyond making technology expenditures tax deductible) may not be effective except as a signalling device; if firms do not wish to do R&D, incentives will not make them, and if they do, incentives are redundant and wasteful. The main aim of policy should be to raise genuine 'demand' for internal technological effort.

- There is a need to distinguish for policy purposes between *different types of public S&T institutions* serving different segments of the technology 'market'. It is not possible for S&T policy to address all their needs in a uniform way. There are basic infrastructure institutions that provide the essential 'public goods' of technology: the standards, metrology, quality and testing institutions. These are essential to competitiveness in any industrialising economy, and some can only be provided by the public sector; however, some can be privatised as purely commercial, and fairly routine, activities (testing). Then there are high-level research institutes: dedicated R&D laboratories in the public sector and universities, which partly conduct basic research and monitor changes in the underlying scientific principles that apply to technology, and partly conduct applied research relevant to industry. These can be much more market driven than they have tended to be in the past, but they also need to keep a core of non-commercial activities in order to generate new knowledge, attract good research talent and keep abreast of changes in scientific changes. Finally, there are extension services, aimed mainly at SMEs; these operate at lower technological levels and their skill and equipment needs are quite different. Each of these has different policy needs.

- *Basic infrastructure (MSTQ) institutions* need to become more efficient in a technical sense to meet the increasingly rigorous and sophisticated demand from firms competing in international markets. They have to promote quality awareness (say, by facilitating the adoption of ISO 9000 and 14000 quality management systems) and provide testing and certification for export markets, diffuse standards, provide metrological services and accredit independent laboratories for testing and certification. One important task is to raise local capabilities to conduct ISO 9000 certification, since foreign services tend to be very expensive, out of reach of all but the largest enterprises. The basic equipment needed for metrology and testing can be very expensive if a large range of industrial activities is to be covered, and the government has to fund the acquisition of such equipment.

- *Research institutions* have to be reoriented (and upgraded where necessary) to serve the needs of the market, while preserving a significant core of research. This generally means imposing 'hard budgets' on the institutions, requiring them to earn a proportion of their revenues from industry. However, there is no general formula on the exact proportion that they should earn – much depends on the country (the more developed the industrial sector the more institutes can earn) and industry (some industries, such as engineering, have greater need for technological services than others) concerned. Making institutes *entirely* market financed is not recommended as a general principle, except for pure service providers with no research content in their work. Moreover, as the economy matures, the science base has to advance also, and it is vital for research institutes to devote sufficient resources to pure research, keeping abreast of major technological trends internationally, and networking with colleagues the world over. Resources have to be provided for this by the government.

- The most difficult part of the process is not changing the incentive system so much as changing the *attitudes and values* of researchers – experience shows that institutional 'culture' cannot be changed overnight, but needs a process of persuasion, retraining and strong leadership. The government can play a lead role not only by changing the incentive systems but also by financing the retraining and culture change, appointing the right leaders and rewarding the most reform-oriented institutions. It should also encourage research staff to become entrepreneurial, setting up spin-off enterprises to commercialise technologies created by research institutions: this is one of the main elements in the success of the (ETRI) electronics research organisation in Taiwan, which has given birth to some of the most successful hardware producers in the world.

- *Technology extension services* are by nature customer oriented, but in most developing countries they have tended to be passive, poorly staffed and badly motivated. They have waited for firms to come to them for assistance, with the willingness to go through length bureaucratic procedures and the ability to formulate their technological needs clearly. SMEs can generally do neither. They need very pro-active service providers that visit their factories, analyse and diagnose their problems and provide a package of services to solve them, covering finance, technology, training, marketing and management. The best extension services in East Asia, in Taiwan, do just this, and are able to keep their SMEs abreast of international levels in many complex technologies. In none of the sample countries were the extension services able to do this. A major policy effort is needed to upgrade their skills, equipment and motivation.

- All S&T institutions have to develop strong '*marketing' capabilities*, creating an awareness and positive 'image' of their capabilities in potential customers, dealing with them in a commercially acceptable manner and paying heed to their complaints and feedback. The most effective S&T institutions have full-fledged marketing and customer feedback departments with systematic procedures. They have to learn the language of industry, which is very different from the language of research. One effective way to induce such a cultural change may be to take the heads of technology institutions on visits to effective counterparts in Europe and elsewhere (the Asian NIEs) to see at first hand how operations and customer relations are managed.

- Many governments are setting up distinct *linkage institutions* to overcome the problems of marketing and 'language'. This is a very positive move and needs to be encouraged, but it must be ensured that the linkage institutions themselves have close links with industry, are managed by private sector oriented personnel, and are able to operate autonomously of the S&T establishment to maintain their credibility with industry.

- The government should encourage and facilitate the emergence of *private technology service providers* so that there is as broad and active a market as possible in this area. Some of these providers may emerge from former public research organisations, but many will come from the private sector: seed capital and encouragement may be advisable here.

- *Technology finance* is essential for undertaking S&T activities and so for creating a vibrant and inter-linked system. Venture capital is in its infancy in all peripheral countries, though efforts are being made to dynamise the industry. Apart from this industry, the government should consider special financial 'windows' for technology investments, perhaps in the commercial banking system but staffed by a different set of people who understand technology and are trained to evaluate its risks and rewards (normal commercial banks are very weak in all such activity). Technology finance should be defined broadly to cover 'minor' as well as major technological activity, including productivity raising efforts.

α S&T policy making should be guided by a *clear strategy and set of priorities*. It is harmful and wasteful for institutions to be subjected to conflicting demands from different ministries or to spread their scarce resources so thin that they have little impact on technology upgrading. The government should decide on priorities, not by arbitrarily dictating which activities to support but by building consensus and general awareness among the constituents. One way to do this is by *Technology Foresight* exercises of the type being conducted in many European countries (and Japan and USA). This involves an iterative procedure whereby research institutions, industry, government officials and academics are brought together to decide on technological challenges, strengths and weaknesses. Priorities are based upon the results of these consultations, with full knowledge of all participants and hopefully their commitment. Mexico is about to launch a Foresight exercise but not, according to available information, any of the other sample countries. It is recommended that they do so, drawing upon the experience of European countries that have completed such exercises recently.

What can the EU do to support technology development in the countries on its periphery? It already has a number of programmes in which less industrialised member countries like Greece can share, as well as measures to help associated countries like Hungary and Turkey. The research for this study suggests that these measures are considered very valuable, especially by research institutions that are starved of resources locally or which gain technologically from associating with advanced institutions in Europe. The direct measures taken by the EU to help firms to upgrade technology are also extremely useful.

However, the study also shows deficiencies in EU policies. In Greece, measures to assist innovative firms may miss out new entrants for the lack of a database on technology institutions, technology needs and firm activities. In Hungary, in the midst of drastic cutbacks on the resources available to research institutions, EU funding for firms to upgrade technology does not, by requiring the participation of an EU partner, pay sufficient attention to promoting linkages with domestic S&T systems. This only deprives the institutions of business but sometimes saddles firms with expensive and inappropriate assistance from western firms unfamiliar with local problems. Research institutions that are directly assisted sometimes find it difficult to locate suitable counterparts in Europe and are sometime made to feel subordinate rather than equals. Turkey cannot participate fully in EU technology programmes since it is not a member, but its participation can be increased on an associate basis to help its S&T institutions build up their capabilities. However, the bureaucratic requirements of some programmes are daunting (especially for smaller firms), and the criteria for assistance are sometimes found to be too narrow and rigid, focusing on 'major' innovation and excluding more mundane but valuable engineering activity. This deters technology transfer and diverts resources from productivity raising to more long-term research.

The implications of these findings are:

š It is important for EU programmes to take a *more positive and flexible* stand on promoting domestic S&T. It would be helpful to launch programmes that specifically target such institutions and linkages.

š *Bureaucratic impediments* to technology collaboration, especially at the enterprise level, need to be minimised, and the net must be cast wider so as to capture a larger range of potential technology actors. The EU should encourage countries to set up databases on technologically active firms and relevant institutions. It should promote its programmes more widely, explaining the procedures and benefits to potential participants.

š One of the most valuable contributions that EU can make is to *strengthen the MSTQ* systems in the peripheral countries. This is already being done by means of direct contacts between institutions; however, a more systematic Community-wide programme of technical and financial assistance would be extremely useful. The objective should be to bring the relevant institutions to minimum levels of 'best practice' in terms of certification, testing, measuring and calibrating capabilities.

- The EU should mount an initiative specifically to *promote ISO 9000* in peripheral countries. There is a great deal to be learnt from measures undertaken in countries like the UK to encourage the spread of ISO 9000: the government subsidised up to half the cost of consultancy, with the result that the UK now has the largest number of ISO 9000 certified firms in the world. Each government is already aware of the importance of spreading the ISO systems through industry, but promotional efforts are not yet coherent and effective, and tend to neglect smaller enterprises.

- The EU should help countries to launch and manage effective *Foresight exercises* to define their technological needs and establish spending priorities.

- The most effective channel of technology transfer from the EU is *direct investment* by its companies. While this is a purely market-driven phenomenon in which European governments should not intervene, the EU can encourage the process of local technology diffusion by promoting subcontracting to host country firms and institutions, undertaking more research locally, and financing the training of manpower in advanced technological functions in their European operations. One possible model may by Singapore's Local Industries Upgrading Programme (LIUP), where a lead MNC contributes a senior procurement executive to the programme, with the salary fully paid by the government, to help potential suppliers upgrade their capabilities to meet its input requirements. The EU could fund such a programme and send experienced company procurement personnel to work with SME suppliers.

- At the more *general levels*, the EU can help technology development by promoting the technical and managerial *education systems* of peripheral countries. Finally, there is a wealth of experience and skills in domestic industrial *technology promotion* in Europe that can be extremely valuable for peripheral countries if a programme could be devised for transferring them at low cost to the host developing or transition country.