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Science and Technology for Development

STPI MODULE 3: THE EVOLUTION OF SCIENCE AND TECHNOLOGY IN STPI COUNTRIES

F. Sagasti

CONTENTS

FOREWORD

This module constitutes an integral part of the Main Comparative Report of the Science and Technology Policy Instruments (STPI) project, a large research effort that examines the design and implementation of science and technology policies in 10 developing countries (Appendixes 1 and 2).

The STPI project generated a large number of reports, essays, and monographs covering a great variety of themes in science and technology for development. More than 250 documents were produced by the country teams and the Field Coordinator's Office, and this proliferation posed rather difficult problems during the comparative phase of the project. It was decided that a Main Comparative Report, covering the substantive aspects of the research work of the country teams would be published, and that several monographs treating specific subjects would complement it.

The Main Comparative Report is organized in three parts. The first consists of a short essay covering the main policy and research issues identified through the research, and the second contains the most relevant results of a comparative nature that were obtained in the project. These first two parts have been published by the International Development Research Centre in a single volume in English, Spanish, and French (109e, 109s, and 109f).

The third part of the Main Comparative Report consists of 12 modules containing material selected from the many reports produced during the STPI project. They provide the supporting material for the findings described and the assertions made in the first two parts of the Main Comparative Report.

The modules were prepared by several consultants, and given the diversity of topics covered, the IDRC staff did not consider it desirable nor possible to impose a single format or structure for their preparation. The reader will find a diversity of styles and structures in the modules and will find that the selection of texts reflects the views of the consultant who compiled the module. However, the modules were prepared in close collaboration with the Field Coordinator and were also submitted to a STPI editorial committee who ensured that they provided a representative sample of STPI material. They should be read in conjunction with the first two parts of the Main Comparative Report.

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HISTORICAL BACKGROUND ON THE EVOLUTION OF WESTERN SCIENCE AND TECHNOLOGY

The roots of Western science can be found in the ancient civilizations of Babylon, Assyria, and Egypt, where systematic records of events - particularly those related to astronomy - began to be compiled (1). At a later stage, beginning with the work of the pre-Socratic philosophers, speculative and abstract concepts about natural phenomena began to evolve, culminating in the work of Plato (who introduced the concept of ideals) and later in the work of Aristotle (who formalized the concept of method and developed formal logic). This allowed, for the first time in history, the development of the capacity to construct and relate abstract conceptions, starting from the empirical perception of the world. This outstanding contribution of the Greeks to Western culture was the embryo from which the scientific method was to develop in the 16th and 17th centuries (2).

During the Roman Empire the pursuit of speculative activities was not encouraged and little of significance was added to the Greek edifice. The notable exception was the work carried out at the Ptolemian Academy in Alexandria, where a relatively large number of scientific concepts and mechanical inventions were developed. It is interesting that many engineering devices, which were to be reinvented centuries later during the industrial revolution, were anticipated by the members of this Academy. Water clocks, pumps, various mechanical devices for lifting weights, war machines, and even a steam turbine were developed by men like Hero, Ctesbius, and Philo. However, the materials of the day and the manufacturing crafts were not sufficiently advanced to translate the designs and experimental devices into fully usable machines. Similar remarks could be made with regard to Archimedes, although a relatively large number of the devices he designed were used in practice (the screw pump, military engines, cranes for lifting heavy objects, etc.) (3).

Although the Romans contributed little to the development of science and their theoretical conception of machines was deficient, they were able to copy, adapt, and employ a large number of technological developments that were the result of other people's work. It has been suggested that "the major contribution of Rome to the advance of technology lay in the ability of its citizens to absorb ideas from elsewhere and to provide an administration that would allow them to be used to their greatest advantage"(4). Nowhere is this skill more apparent than in public health works and in construction. The aqueducts, the use of pumps to provide running water, and the invention of the hospital system all testify to the adaptive and organizational skills of the Romans, as does the wide diffusion of water mills, screw presses, and other mechanical devices used in productive activities (5).

After the decline of Rome the Greek tradition was continued in the Byzantine Empire and in the Arab world. There it was maintained and further developed, partly because Islam acted as a bridge between the civilizations of the Indus Valley and those of Western Europe. The wide-ranging contributions of a large number of Arab scientists made the Islamic Empire the centre of intellectual life during the Middle Ages (6). Furthermore, as a result of the expansion of the Islamic Empire, and particularly through the work of the great Arab translators, the writings of Aristotle, Plato, and other Greek authors reached Europe during a period ranging from the 11th to the 13th century.

The reintroduction of Greek thought - both in the sciences and in literature - provided the foundations for the Renaissance movement, which brought with it a revaluation of manual labour and would signal a return to the concern for natural phenomena and empirical observation (witness the work of Leonardo and many other great painters). Thus the Renaissance saw the beginnings of the full process of contrasting abstract conceptions with physical phenomena, which is the mark of Western science to our day. The works of Copernicus, Vesalius, Gilbert, and Bacon (who systematized the methodology of science of his age, emphasizing the empirical and inductive aspects of it) signaled the transition toward the fully fledged scientific revolution that was going to change man's conception of the universe, leaving behind the dogmatism that characterized the Middle Ages (7). The works of Galileo, Kepler, and Newton would inaugurate the era of the "New Instauration," as Bacon called it, which brought with it the idea that natural phenomena were predictable and controllable and could be mastered through understanding.

But in spite of the predominance of dogmatic disquisition (or perhaps because of it), the Middle Ages contributed substantially to shaping the Western mind, particularly through the idea that there was a certain divine order to the events taking place in the world. Whitehead has emphasized this aspect of the evolution of Western thought:

"But for science something more is wanted than a general sense of the order in things. It needs but a sentence to point out how the habit of definite exact thought was implanted in the European mind by the long dominance of scholastic logic and scholastic divinity. The habit remained after the philosophy had been repudiated, the priceless habit of looking for an exact point and of sticking to it when found ....

"I do not think, however, that I have even yet brought out the greatest contribution of medievalism to the formation of the scientific movement. I mean the inexpugnable belief that every detailed occurrence can be correlated with its antecedents in a perfectly definite manner, exemplifying general principles. Without this belief the incredible labours of scientists would be without hope. It is this instinctive conviction, vividly poised before the imagination, which is the motive power of research: that there is a secret, a secret which can be unveiled. How has this conviction been so vividly implanted on the European mind?

"When we compare this tone of thought in Europe with the attitude of other civilizations when left to themselves, there seems but one source for its origin. It must come from the medieval insistence on the rationality of God ...." (8).

In parallel with these developments in human thought, and taking off from where the Romans had stopped, the Middle Ages witnessed the slow but continuous evolution of productive techniques. Road building, construction of canals and waterways, improvements in shipbuilding, and the introduction of new types of plows all took place during the early Middle Ages. These were to be followed by the development of crafts and guilds, by significant improvements in construction (particularly castles and churches), by the widespread use of watermills, and by the resurgence of technical activity stimulated by the contact with Eastern cultures. These led to improvements in textiles, mosaics, irrigation, silks, paper, etc. (9). During this period a great variety of local technological responses, suited to the particularities of the local environment and widely diffused throughout society, were developed. Mumford has called this stock of technological responses the "polytechnic heritage" of the Middle Ages and has pointed out:

"The great feat of medieval technics, then, was that it was able to promote and absorb many important changes without losing the immense carryover of inventions and skills derived from earlier cultures. In this lies one of its vital points of superiority over the modern mode of monotechnics, which boasts of effacing, as fast and as far as possible, the technical achievement of earlier periods ...Some of this polytechnic advantage was due to the fact that skills, the esthetic judgement and appreciation, and the symbolic understanding were diffused throughout the whole community, not restricted to any one caste or occupation. By their very nature, polytechnics could not be reduced to a single, standardized, uniform system, under centralized control" (10).

The great geographical discoveries of the 15th and 16th centuries helped greatly in opening up even more the varied technological pool inherited by Western Europe from the Middle Ages. At the same time they also stimulated intellectual activity by posing new challenges that defied the conceptual frameworks inherited from earlier ages (11). Crafts continued to develop and diversify well into the 16th century, following the pattern established throughout the Middle Ages and the Renaissance. But gradually, starting in the 17th century, the traditional crafts were replaced by more rigidly organized manufacturing methods, guilds began to break down, and a more tightly structured division of labour in manufacturing began to emerge. The reduction in technological variety took place concurrently with the development of the capitalist mode of production, in which the worker was no longer the owner of the means of production. This process was hastened by the needs imposed by war and the manufacture of arms, as France, Sweden, and even Russia established arms factories where serial production required that the manufacturing process be divided into many steps, in which each worker performed only part of an operation (12).

The transition from manufacturing to modern industry, what Marx called the "emergence of large-scale industry," was facilitated by the development of new sources of power - mainly the steam engine - and by the development of metallurgy to the point that steel could be manufactured in large quantities and worked with precision, so that machines could be used to produce machines. This signaled the beginning of a transition from a polytechnic age of local and varied technological responses to a monotechnic age in which this variety began to be reduced and a specific production technique replaced the others because of its greater efficiency.

The two currents - the growth of science and the evolution of technology - began to interact more closely starting in the middle of the 17th century. In this way the "scientific revolution," which represented a breakthrough in understanding, and the "industrial revolution," which represented a breakthrough in productive activities, started a process of merger that would become complete only in the 20th century. In the 16th century science had become indispensable for navigation, and during the 17th and 18th centuries the interaction between science and production was intensified, although it is generally acknowledged that during the earlier stages of this process technical advances contributed more to the development of science than science to the development of productive techniques. Bernal has pointed out:

"The major transformations that characterize the great Industrial Revolution - from wood to coal as fuel; from wood to iron as material; from horse and waterpower to steam power; from single to multiple action in spinning - are all products of the ingenuity of workmen acting under the triple economic drive of increasing markets, the resultant shortages of traditional materials, and production bottlenecks due to the lack of labour. They were made possible only by the availability of capital for making the new machines. All of this might have happened without science, but it could not have been done so quickly" (13).

There has been a controversy among economic historians centred around the relative importance of the different factors that contributed to the industrial revolution, and in particular to the inventions and innovations that characterized it (14). The view generally accepted at present coincides with the statement by Mathias:

"The simplest assumptions of causation flowing directly and in one direction need to be questioned; the presumption that connections between science and industry were direct, unitary, simple ....It can be argued that the many other conditioning factors in technical change were collectively of much greater importance during the first century of industrialization and that, in the immediate context of manufacture, formal scientific knowledge was much less strategic in determining commercial success than some modern studies have suggested. In longer perspective we may see that the main impetus from formal applied science to innovation came after 1850 on an ever-widening front, but in a context which was highly favorable for many other reasons" (15).

During the 19th century the predominance of empirically developed productive techniques was to give way to the rise of new industrial activities based on scientific discoveries. The two industries in which this transition was clearly visible toward the end of the 19th century were the electric and chemical industries, particularly with the development of the telegraph, the telephone, and new synthetic materials. The interaction between science and industry during this century also took the form of scientific studies of established industrial processes, such as the use of steam engines and the production of steel, which led to new scientific generalizations (16).

As the century progressed, a greater number of instances were to be found where scientific discoveries preceded the development of productive techniques (the discoveries of Henry, Faraday, Oersted, Clerk-Maxwell, and Hertz anteceded respectively the work of Morse on the telegraph, Siemens on the dynamo, Jacoby on the electric motor, and Marconi and De Forest on the radio). This led to the new phenomenon of systematic and premeditated invention and, at a later stage, to the emergence of the industrial laboratories, such as Arthur D. Little in Boston and Edison's laboratory in Menlo Park, where several scientists and engineers of various disciplines joined forces in applying the scientific method to the solution of technical problems in production (17).

Thus the growth of science and the evolution of productive techniques became closely intertwined during the 19th century, particularly after the 1950s. In 1858 W.J.M. Rankine could state in his "Manual of Applied Mechanics":

"The extent of intercourse, and of mutual assistance, between men of science and men of practice, the practical knowledge of scientific men, and the scientific knowledge of practical men, have been for some time steadily increasing; and that combination and harmony of theoretical and practical knowledge - that skill in the application of scientific principles for practical purposes, which in former times was confined to a few remarkable individuals, now tends to become more generally diffused."

The fusion of these two currents took place in Western Europe amid great social upheavals, concurrently with the emergence of capitalism as the dominant mode of production, with the expansion of trade, and with the spread of market economies both within Europe and at the international level. The role played by the colonies in this process has also been the subject of great debate, although it is clear that they provided much-needed raw materials and also a market for manufactured products (18). The emergence of the first industries based on scientific discoveries and the establishment of the first industrial laboratories also coincided with the monopolistic phase of capitalist expansion at the turn of the 19th century (19).

The full merger of science and production in the late 19th century took place at the same time that traditional productive techniques - of lower efficiency according to the economic criteria prevailing at the time - were being discarded, abandoned, and forgotten. The reduction in the variety of technological responses, which had been developing slowly and cumulatively since the Middle Ages, was greatly accelerated. Mumford has dwelled on this aspect of the rise of modern industry with particular acrimony:

"As late as the middle of the nineteenth century an immense technological heritage was still in existence, widely scattered among the peoples of the earth, every part of it colored by human needs, environmental resources, inter-cultural exchanges, and ecological and historical associations ... one may talk of a technological pool: an accumulation of tools, machines, materials, processes, interacting with soils, climates, plants, animals, human populations, institutions, cultures. The capacity of this technological reservoir, until the third quarter of the nineteenth century, was immensely greater than before: what is more, it was more diversified - and possibly quantitatively larger, as well as qualitatively richer - than that which exists today. Not the least important part of this technological pool were the skilled craftsmen and work teams that transmitted the colossal accumulation of knowledge and skill. When they were eliminated from the system of production, that vast cultural resource was wiped out.

"Western man's pride over his many real achievements in mechanization made him too easily overlook all that he owed to earlier or more primitive cultures. So no one has yet attempted to make an inventory of the massive losses resulting both from the neglect and deliberate destruction of this craft heritage, in favor of machine-made products. While the population of complex and technically superior machines has enormously increased during the last century, the technological pool has actually been lowered as one handicraft after another has disappeared.

"The result is that a monotechnics, based upon scientific intelligence and quantitative production, directed mainly toward economic expansion, material repletion, and military superiority has taken the place of a polytechnics, based primarily, as in agriculture, on the needs, aptitudes, interest of living organisms: above all on man himself" (20).

Thus the fusion of the growth of science and the evolution of modern industrial technology led indirectly to the demise of traditional crafts and the disappearance of technologies that could not withstand the competition from new products and processes. Incidentally, the current awareness of environmental problems and ecological damage has spurred many initiatives to rescue these traditional crafts and to make technology more adjusted to human needs and capabilities (21).

The subsequent evolution of the interactions between science, technology, and production in the Western European countries, and also in the United States, Japan, and the Soviet Union, is well known. The acceleration of the pace of technical progress during the last 80 years has been extensively documented (22), and it will be sufficient to point out a few milestones, such as the replacement of the individual inventor by organized industrial laboratories, which started around 1890, the large-scale involvement of scientists in war for the first time during World War I (23), and the widespread diffusion of technical skills and values, which was brought about by the improvements in the internal combustion engine and the mass production of automobiles.

The period between the two World Wars witnessed the great advances in physics, which would culminate in the development of the atom bomb, as well as the expansion of the chemical industry as a result of the new discoveries in chemistry. Lastly, World War II and the postwar period can be characterized as the age of scientific explosion, in which advances in electronics, biology, chemistry, cybernetics, and many other fields have made the results of the scientific activity a major source of productive techniques, and in which research and development activities have taken a prominent place in industry.

According to Freeman: "What is distinctive about modern industrial research and development is its scale, its scientific content and the extent of its professional specialization. A much greater part of technological progress is now attributable to research and development performed in specialized laboratories or pilot-plants by full time qualified staff ...The professionalization (of research and development) is associated with three main changes:

"1. The increasing scientific character of technology. This applies not only to chemical and electronic processes but often to mechanical processes as well ...

"2. The growing complexity of technology, for example, the partial replacement of 'batch' and 'one-off' systems of production by 'flow' and 'mass' production lines ...

"3. The general trend towards the division of labour ...which gave some advantages to the specialized research laboratories, with their own highly trained manpower, information services and scientific apparatus" (24).

In the countries that have an endogenous scientific and technological base, the rise of science-related industries has been accompanied by an enlargement of the minimum critical mass of resources to do science and by an unprecedented expansion in the magnitude of the scientific and technological effort. As an example, Machlup (25) estimates that more than one-third of the economically active population of the United States is related in some way to the "knowledge industry" (research, experimentation, teaching, information, etc.).

Therefore, in retrospect, the last 400 years have seen - in the countries that have an endogenous scientific and technological base - the emergence of the profession of generating knowledge in a cumulative and organized way, and have witnessed the transition fr m scientific activity practiced by a few gifted individuals to that carried out by an incipient collectivity of scientists, and to that performed by a truly international scientific community at present. This community acquired legitimacy not only because of the increasingly coherent explanations that it gave to natural phenomena and, to a lesser extent, to social phenomena, but primarily because it demonstrated its usefulness for the development and improvement of productive techniques, something that was anticipated by Bacon 4 centuries earlier when he stated that "knowledge in itself is the base of power." It is appropriate to add that the centre of gravity of this scientific community has not remained static, and Ben-David (26) has pointed out that it has shifted from Italy to the Netherlands, to England, to France, to Germany, and later to the United States. However, these displacements took place without losing the continuous and cumulative character of scientific activities.

It is important to dispel the notion that the evolution of productive techniques, the growth of science, the process by which they merged, and the abandonment of traditional crafts took place in a conscious, ordered, and planned manner. They rather occurred spontaneously, covering a wide field, duplicating efforts, with false starts starts, and showing a series of contradictions. Nevertheless, the self-correcting character of the scientific enterprise allowed for changes in orientation and direction, but always within the general lines established by the conjunction of interests of scientists, engineers, and those in industry or the state who had the power and resources to underwrite the performance of scientific activities.

Another aspect that accompanied the symbiosis of science and production during the emergence of modern industry was the diffusion throughout society of the values and the thought habits associated with the scientific and technological revolution. The idea that it is possible to understand, predict, and control the phenomena around us and that man can transcend the limitations imposed by nature has had great influence on the development of the countries that have an endogenous scientific and technological base. According to Landes:

"When all the complicating circumstances are stripped away - changing technology, shifting ratios of factor costs, diverse market structures in diverse political systems - two things remain and characterize any modern industrial system: rationality, which is the spirit of the institution, and change, which is rationality's logical corollary, for the appropriation of means to ends that is the essence of rationality implies a process of continuous adaptation. These fundamental characteristics have had in turn explicit consequences for the values and structure of the economy and society" (27).

This stands in marked contrast with the situation of most countries that lack an endogenous scientific and technological base and that adopted, primarily through imposition, the products of Western civilization without internalizing the processes, attitudes, and values that led to them (28).

THE SPREAD OF WESTERN SCIENCE AND TECHNOLOGY IN THE STPI COUNTRIES

The fusion of science and industrial production, which characterized Western civilization, was a phenomenon limited to a few countries, first in Western Europe and later in the United States, Japan, and the Soviet Union. The vast majority of countries in Africa, Asia, the Middle East, and Latin America did not participate in this process. Referring to the 19th century, when this fusion finally took shape, Bernal pointed out:

"...the working classes of the industrialized countries and the peasants from underdeveloped countries, which began to be incorporated into the world markets, hardly received anything from the new science and technology ....Even though the effects of science expanded during the century, it continued on being a patrimony of a small part of the world. Only the Western European countries and the recently industrialized areas of the United States made contributions to modern science. The rest of Europe and all Asian and African countries remained at the margin, for the exploitation of their inhabitants was something inherent to the very existence of industrial capitalism" (29).

These differences have become even more pronounced during the 20th century, accentuating the sharp contrast between countries that have an endogenous scientific and technological base and those that have an exogenous base.

The Third World countries have accepted the products of Western industrial civilization, but without internalizing the processes that led to them. Thus improvements in health, education, and material production, and above all the spread of modern communications, have created a series of distortions and have raised aspirations beyond the level at which they can be satisfied. Furthermore, Western civilization - bringing new products, technologies, organizations, institutions, values, etc. - was generally superimposed on traditional cultures that had developed independently over a considerable period. Some of these civilizations had reached a relatively high level of development, as measured by their own standards. The imposed insertion of Western technology and ideas forced a cultural breakdown of significant proportions. However, none of the high civilizations of Asia, America, the Middle East, or Africa was at the verge of producing on its own a transformation comparable to the scientific and technological revolution that took place in Europe (30).

The three strands mentioned in the preceding section - the growth of science, the evolution of modern productive techniques, and the stagnation of traditional crafts and practices - have had their own peculiar characteristics in the former colonies. In science, because the colonies were really at the margin of the scientific centres of Europe, the development was mostly imitative and was the work of a few isolated but highly motivated and gifted men. In modern productive activities, manufacturing in particular, the productive techniques of the colonizers were adopted and the technological base reflected the spread of mercantilism and later of more advanced forms of capitalism. Traditional and indigenous technologies suffered a substantial loss of variety, as products and techniques were replaced, and in some cases completely wiped out, by the introduction of Western technology. Furthermore, with very few notable exceptions, there was practically no contact between the introduction and local growth of Western science and the implantation of new productive techniques: the two processes remained isolated from each other and did not interact as happened in Europe.

The diffusion of Western science throughout the Third World countries has been an irregular process, entailing a partial acceptance of results but without full knowledge of the cumulative process that originated them. The practice of science in these countries was, to a larger extent than in the European countries, an activity of the elites, of isolated pioneers who lacked an organic connection with their social environment, at least insofar as their scientific activities were concerned. Their efforts were usually out of phase, because the frontiers of knowledge were being explored in other parts of the world and they received information on advances and discoveries with inevitable delays (31).

Thus the pursuit of science did not develop firm roots in the majority of these countries until the 20th century, and even then it acquired a fragmentary, reflexive, and imitative character and was usually divorced from production. Science was oriented primarily toward the main centres of knowledge, located outside the developing countries, and the concern for local problems emerged to the extent that it was necessary to know the environment better for a more intense exploitation of resources, or to the extent that curiosity and the possibility of contributing to the advance of knowledge motivated scientists, both foreign and local, to focus their attention on the specific problems of the region.

The nature of transplanted productive activities, and thus of the technology employed, was conditioned first by the interests of the colonial powers and, after political independence was won by some countries (particularly in Latin America), by the form in which their economies were incorporated in the international division of labour that accompanied the expanion of the capitalist system of production. For this reason the productive activities in these countries were oriented toward the extraction of natural resources or toward the generation of a surplus to be transferred abroad.

The productive techniques that were utilized in extractive and manufacturing industries were almost totally imported and thus alien to the environment where productive activities took place. Furthermore, as these implanted activities grew in importance, the grafted technological base began to expand, leading to the acquisition of a superficial layer of technical knowledge disconnected from the physical and social reality and depending on foreign sources for its maintenance and renewal. Nevertheless, a certain crossbreeding and intermingling of implanted and indigenous technologies took place, particularly in those areas of production that were geared toward the local market (clothing, housing, household goods, etc.). A large proportion of these "intermingled" technologies were to disappear at a later stage when the process of industrialization - based primarily on import substitution and the use of modern manufacturing techniques - took place during the 20th century.

With reference to the traditional technological base, it is possible to say that after a brief initial period of acculturation during which the colonizers learned to operate in an alien environment, the autochthonous non-Western technological tradition, which had been developing slowly and cumulatively for a long time, was eliminated or marginated because it did not serve directly the interests of the colonizers or capitalists. Some of these activities were maintained to the extent that they provided the means of subsistence to those who were engaged in the implanted productive activities. Other activities were partially combined with some aspects of the implanted technology to generate the intermingled technologies mentioned above. But in general the transition from what Mumford called the "polytechnic age" to the "monotechnic age" was particularly drastic in the developing countries, and a large number of local technical responses were lost.

The Emergence of Science in the STPI Countries

The way in which Western science was introduced into the STPI countries is examined next, and it is appropriate to begin with a cursory review of the local situation prevailing at the time Western science began its spread.

In Latin America, the Aztec, Maya, and Andean civilizations had reached considerable levels of material, social, and intellectual development before the conquerors erupted into the local scene during the first half of the 16th century. The agricultural and engineering achievements of these peoples have been recognized widely, as have their forms of social organization, which, as was the case in the Andean region, guaranteed the subsistence and material well-being of the population. Murra (32) has described the way in which local ethnic groups, under the aegis of the Inca Empire, weaved social and technological knowledge to ensure the appropriate utilization of the diversity of ecological conditions in the coastal, highland, and jungle regions of ancient Peru. Furthermore, Patiño (33) has pointed out that in spite of generally adverse conditions for agriculture, there is no evidence of massive and prolonged famines in the pre-Columbian world.

Although all the high civilizations of Central and South America kept fairly accurate records of astronomical observations, usually in relation to agricultural activities, it was the Mayas who developed the skills of systematic observation to the highest degree. This is closely linked to the fact that the Mayas were able to develop a written language, which helped in the recording and study of sidereal events. Developments in mathematics, which included the use of the zero, and in astronomy, which involved the use of tables to predict eclipses, were tied to astrological and religious viewpoints, with the priests playing the main role in the accumulation and transmission of knowledge (34).

Thus the ancient civilizations of America had developed a substantial base of knowledge before the advent of the Spanish conquerors. It developed cumulatively, starting from the direct experience and personal mastery of trades and artisan activities and evolving toward the oral and written transmission of empirical and speculative knowledge (35).

The first 50 to 100 years of the conquest saw a complex process of acculturation, involving a two-way transfer of knowledge, products, and techniques. The Spanish conquerors learned to operate in an alien environment and brought with them a cultural and technical baggage that had to be adapted to the American situation, while in return many animal, vegetable, and handicraft products were transferred from America to Europe (36). The impact of the Spanish conquest stopped the gradual evolution and development of practical and speculative knowledge, disrupted the social fabric, and led to the crossbreeding and uneasy coexistence of the European and local technological traditions.

In the Middle East, particularly in Egypt, the outstanding contributions of earlier ages - the Pharaonic, Alexandrian, and Islamic periods - had receded into the past during the decline of the Ottoman Empire and while Europeans began to expand their sphere of influence. According to Said and Zahlan:

"In the 16th century, when the occupation of present day Syria, Egypt, Lebanon and Palestine took place, the Ottomans clearly commanded a position of great strength; this was so because their military and administrative prowess was vastly superior to the conditions prevailing in Europe. The empire was then open to the circulation of thoughts, ideas and events, both locally and abroad. But gradually the Western world overtook the Ottoman Empire. European military technology and power began to grow to such an extent that it could hold its own and ultimately challenge those of the Ottomans; the final and lasting test of strength came when the Ottoman attempt to storm Vienna met with total defeat. The treaty of Carlowitz (1699) following this confrontation marked the beginning of the decline of the Ottoman Empire. As it declined, it became more and more introverted and isolated; the Arabs living in the empire suffered accordingly. The stagnation became so acute that few, if any, of the discoveries of Europe reached the region, and soon a state of intellectual backwardness set in" (37).

This state of intellectual backwardness at the end of the Ottoman Empire stood in marked contrast with the situation prevailing when Islamic civilization flourished a few centuries earlier. The great Arab scientists and translators had been instrumental in reintroducing into Europe the Greek ideas, and Arab contributions to mathematics, philosophy, alchemy, and other fields of knowledge had been most significant (38). This was put to an end by the expansion of Western Europe, following a long period of domination by the Ottoman Empire, which had already reduced the level of Islamic intellectual activity in the Middle East.

Before the advent of Western civilization through the British conquest, India had reached a high level of practical and speculative knowledge, and numerous advances in astronomy, medicine, chemistry, metallurgy, agriculture, and textiles testify to this. Furthermore, developments in philosophy and abstract reasoning, particularly in mathematics, also took place. Rahman et al. have pointed out:

"Looking back at the developments of ancient India we notice the development of technology on the one hand and the development of abstract thought based on observation, logical and mathematics analysis ...

"There is also evidence of an early school of thought which seems to have relied on a naturalistic mode of explanation, through analogy of processes developed and controlled by men" (39).

Developments in ancient India paralleled in some way those that took place in ancient Greece and medieval Europe, although Rahman et al. also point out that the processes of development of abstract thought and empirical observation did not become organically linked: "The impact of this mode of thought, which is in line with the present day scientific outlook, cannot be evaluated, since hardly any literature has survived the vagaries of time. The success of logical analysis, however, appears to have been greater, which divorced from observation in the context of sociological factors, was soon to lead to pedantry" (40).

During the Middle Ages the development of thought and the development of technology in India continued along parallel paths. The close contact between the Sanskrit and Arabo-Persian literature during this period provided a new stimulus to inventiveness, although it led more to the absorption and cross-cultural transfer of existing knowledge than to new developments. At the end of the Middle Ages, just before the Europeans intervened, India was not on the verge of scientific and technological revolution comparable to that of Western Europe, although there were considerable developments in technology and in speculative knowledge. Among the reasons for this, Rahman et al. point out two of great importance:

"The main failure (of Indian science and technology), however, is two-fold: quantification of knowledge and practice, and the development of tools of enquiry. The lack of quantifying the phenomena is due to the lack of correlation of mathematics and its development with other sciences. This is surprising in view of the resurrection of Sanskrit literature and existence of considerable mathematical activity.

"The second failure in developing tools of enquiry applies both to experimental techniques, and the equipment and apparatus required for it, as well as that of notation, i.e. similar to what was developed in the West in chemistry and in mathematics. It may have been this deficiency which prevented them from understanding Western developments in their own works" (41).

Korea also achieved, independently of the West, a rather high degree of development in areas such as astronomy, printing, weaving, and handicrafts (42).

For a considerable time the overwhelming influence of China had been a main conditioning factor in the development of a Korean scientific and technological tradition, even though Chinese science and technology were not accepted without modifications and adaptations to make them more suitable to local conditions. The peak in Korean scientific achievements came during the 15th century under the Yi dynasty in a variety of fields, including astronomy, geography, ceramics, painting, architecture, medicine, and agriculture. The Japanese invasion during that century was a cultural and social disaster of the first magnitude and put an end to the development of an independent Korean scientific and technological tradition. For a long time Korea would act as the main transmitter of technological and cultural innovations to Japan.

In Korea the empirical and technical tradition prevailed over theoretical speculations. According to Jeon:

"We can discover the origin of Korean science in the technical tradition of the craftsmen who passed down their practical experiences and skill privately from generation to generation. They devoted themselves only to the search for phenomena and neglected theoretical explanations. The result of attaching importance to empirical research instead of theory was that technique was developed apart from any systematic experimental method" (43).

The introduction of Western culture, which involved a radical break with local traditions, was delayed until the late part of the 19th century, toward the end of the Yi dynasty, and was spearheaded not by the European powers but rather by the United States and Japan. Shortly after Western products, techniques, and ideas were introduced, with the corresponding transfer of technologies to manufacture small arms, explosives, paper, and leather goods and to improve agricultural and mining activities, Korea was invaded by Japan and remained under Japanese rule until the end of World War II.

Macedonia has had a rather turbulent history of foreign invasions, which include the conquest by the Byzantine Empire, whose domination lasted from the 5th to the 9th century, and the Bulgarians, who displaced the Byzantines. In that period, St. Clement and St. Naum, the followers of St. Cyril and St. Methodi, introduced the Cyrillic alphabet and established the first Slavic university in Chrid.

An uprising of Macedonian slaves led to liberation in the second half of the 10th century, but freedom was lost when Byzantium conquered Macedonia again. At the close of the 13th century Serbian invaders took over Macedonia, to be driven away a century later by the Turks. Macedonia remained under Turkish domination for 5 centuries during which many uprisings were crushed, and became free only at the beginning of the 20th century.

This economic and political environment was not conducive to the development of a tradition of scientific and technological activities, and although the Macedonians had a university during the 10th century, and artistic activity during the 11th and 12th centuries (particularly the frescoes) anteceded the European Renaissance, there was little that could be called Macedonian in the way of scientific activities and technical developments until the end of the 19th and the beginning of the 20th century.

The general picture that emerges regarding local technological activities and speculative thought in the STPI countries before the arrival of Western science suggests that in most of them there was a well-developed indigenous technological base, geared primarily to the production of handicrafts, to architectural and engineering works, and to the performance of agricultural activities. Highly developed forms of social organization prevailed in most of the STPI countries, and the development of speculative thought had reached a significant level in some cultures, although unevenly and divorced from systematic observation.

The introduction of Western technology into the STPI countries (with the exception of Macedonia) seriously disrupted the local technological tradition and led to a significant loss of variety. Said and Zahlan (44) have pointed out how, during the last years of the Ottoman Empire, the introduction of Western products destroyed the local artisan and handicraft industry. Bhattasali has emphasized the process by which the invasion of British products led to the diminishing of traditional crafts and traditions in India:

"With the establishment of British rule, Indian industries began to disappear, under most coercive measures. Her numerous artisans began to lose their traditional vocations, swelling the ranks of unemployed agricultural labour. The unsurpassed quality of her textile goods - cotton, silk or woollen produced in considerable quantities - had been a major source of income to her economy both from the national and international markets. To make room for British products, these became the main targets of attack through the harshest fiscal and tariff measures. To curb the production of the world famous muslin cloth manufactured in the city of Dacca the (East Judia Company) officials went to the extent of cutting off the fingers of the weavers" (45).

The situation was more favourable in the more remote places of America, where distance provided a natural protection to local artisan production, and the local technological tradition managed to survive in some way or other. The statement by Ravines regarding Andean technology could well be generalized to other regions:

Many of the industries practiced during the pre-Hispanic period survived without change or with little modification until our days. If one remembers how artisan practices were transmitted from masters to apprentices, from fathers to sons, and that for centuries, and even millennia, manufacturing and construction methods have survived, it then is necessary to suppose that their disappearance was exclusively a consequence of the drastic rupture in the cultural tradition ...sufficient to alter the harmonious relation established between man and nature throughout the ages.

"In the Central Andes, in spite of the five hundred years of Spanish culture, it is not difficult to appreciate today this cultural continuity. In many parts of the territory, particularly in the areas that were occupied by the ancient Peruvian cultures, the picture is particularly clear, and it could be possible to obtain, without too much effort, first hand data on the industries and arts which the archeologists have reconstructed laboriously from fragmentary evidence" (46).

Western European culture and the scientific outlook that accompanied it were superimposed on the indigenous traditional civilizations of the conquered lands. In this process the cultural and scientific situation of the colonizing power, as well as the timing of colonization, deeply affected the way in which the European modes of thought were to be implanted in the new lands. Thus the differences between India, Latin America, and the Middle East with regard to the absorption of scientific ideas stem more from the characteristics of the scientific enterprise in the United Kingdom, the Iberian peninsula, and the United Kingdom and France respectively. It is also necessary to take into consideration that the American conquest took place during the Renaissance, when the scientific revolution was still in the making, and that the colonization of India and Egypt took place shortly after the industrial revolution had borne its first fruits.

Spain had maintained a front-line position in the intellectual revolution that took place during the Renaissance, for she played a key role in the transmission of classical knowledge to the West and had remained in close contact with the great centres of Italian humanism. The discovery of America and the intellectual and social tensions that it brought, as well as the close interaction Spain maintained with other European centres, helped to prepare the ground for the scientific and technological revolution that was to take place in Europe during the 16th and 17th centuries.

However, this situation began to change radically starting in the last third of the 16th century. Lopez Piñero (47) has pointed out that this was for three reasons: the triumph in Spain of the counterreformist mentality, which brought about the predominance of scholasticism and the imposition of ideological isolation (exemplified by the prohibition by Philip II of Spaniards from studying or teaching abroad); the overriding concern with practical matters, which was not unrelated to the social tensions arising out of the conquest of America, and which focused all efforts on the development of applied knowledge to the detriment of abstract science; and the extermination of the Spanish-Jewish community, which had been the most important social group from the point of view of scientific activities during the Middle Ages, and which could have provided a channel to link the medieval tradition and the advances of the Renaissance with the emergence of modern science in the 17th century.

For these reasons Spain did not participate in any of the great scientific developments of the post-Renaissance period. According to Lopez Piñero:

"...Spanish science during the 17th century can be divided into three different periods. During the first, corresponding approximately to the first third of the century, our scientific activity was mere prolongation of that of the Renaissance, ignoring completely the new ideas. The second period, which corresponds roughly to the central forty years of the century, is characterized by the introduction into the Spanish scientific environment of some modern elements, which were accepted as mere corrections of detail to the traditional doctrines, or simply rejected. Only during the last two decades of the century, some Spanish authors broke openly with the classical schemes and initiated the systematic assimilation of new currents" (48).

As a result Spain remained at the margin of the new European developments during the 17th century, which was precisely the formative period of modern science. The break with its medieval and Renaissance traditions made it impossible a century later to take advantage of earlier developments and to merge them with the new ideas and pursue scientific undertakings vigorously. Furthermore, Lopez Piñero also points out that it was only after 1682 that Spanish society began to react timidly against the "legal dishonour" of manual work, the rejection of which was a necessary condition for engaging in experimental activities and developing industry-related science.

This situation could not help but affect the nature of intellectual activities that took place in the Spanish colonies. The rigidly centralized control that was maintained during the first 2 centuries of the colonial period, and the overwhelming influence of religious orders, would seriously limit the range of scientific activities that could be and were undertaken. A similar situation prevailed in Portugal, although it took an even more extreme character and affected even more negatively the development of intellectual activity in Brazil. Nevertheless, during the brief period of Dutch dominance in Pernambuco between 1630 and 1654 a number of scientists were brought to Brazil, but they left after the Portuguese took over again (49).

With regard to the Indian subcontinent, the early settlements of Dutch and Portuguese merchants, as well as of Jesuit missionaries, led to a few isolated instances where incipient scientific activities of the descriptive type were carried out. In contrast with America, at the time of the British conquest of India the Industrial Revolution was developing at a fast pace. Furthermore, the British were clearly conscious of the importance of acquiring systematic knowledge about the region they were to exploit, and this was a factor conducive to the performance of scientific and technological activities in India, primarily by the colonial power.

The Napoleonic invasion of Egypt at the close of the 18th century, which brought a large number of scientists and naturalists to study the region, and the foundation of the short-lived "Institute de l'Egypte" were the first attempts to introduce Western science into the Middle East. France was at that time one of the main European centres of scientific activity (50), and it was natural that scientific concerns would extend to the newly conquered regions. Subsequently, Britain became involved in Egyptian affairs, displacing the French.

The nature of scientific activities performed in the newly conquered regions had a definitely colonial flavour. Early research in natural history in India was clearly motivated by commercial purposes, and Sen has pointed out:

"Behind all such apparently disinterested efforts to advance natural history in India, as elsewhere, lay the urge to find, transplant and acclimatize plants of economic and medicinal promise, around which centered so much political and economic rivalries and strife of the 17th and 18th century ...

"If considerations of economic exploitation motivated botanical researches, it is superfluous to emphasize the imperial needs of the East India Company to embark upon extensive programmes of carrying out trigonometrical, hydrographic, geodetic and geological surveys to ensure the military, administrative and economic control of the sub-continent" (51).

Furthermore, in the cases where apparently no direct commercial or economic motives were to be discerned and research was oriented toward the generation of knowledge, European scientists working in the new lands did not perceive their activities as something to be organically integrated into the incipient local intellectual community. Thus even in Latin America, after the scientific revival had taken place in Spain during the reign of Charles III at the end of the 18th century, most scientists, both European and local, turned their eyes toward the scientific centres of Europe. The statement made by Safford regarding the research of two French naturalists in Colombia in the early 19th century (shortly after independence had been won) could be taken as representative of the interests of most scientists during the colonial period:

"Once the phenomena were observed and the specimens collected, however, the European scientists naturally looked to the scientific communities they had left and that provided their professional frames of references. Bousingault and Roulin had never looked upon their venture to the New World as more than an extended field trip" (52).

These considerations indicate that the Europeans' concern for scientific activities in the newly conquered areas was seen primarily as an extension of the pursuit of science in their own lands, and that utilitarian motives were behind the researches of a more applied nature. All of this conforms to the model that Bassalla (53) has described as the pattern of "colonial science" and it did not contribute to the establishment of an independent and cumulative intellectual and scientific tradition.

In spite of this, science grew to a limited extent in some of the colonies, particularly in Latin America, where it had a more practical character. Roche has pointed out:

"Spanish American science in the colonial period was highly practical in its motivations, and this can be best exemplified by the setting up of the amalgamation process in the 16th century, the botanical expeditions, the anthropological studies of Bernardino de Sahagún, the adaptation of many species of plants and animals brought from Europe, the founding of the Royal College of Mining in Mexico in the 18th century, and the vaccine expedition in the early 19th century" (54).

Early scientific endeavours were the work of a few gifted men working in isolation, and the history of science in Latin America has taken up to now a biographical approach, describing the life and work of these outstanding scientists (55). Of great importance in the introduction of Western science, although filtered through religious eyes, were the efforts of religious orders, particularly the Jesuits, who commanded a dominant position in education in both Spanish and Portuguese America through the 17th and part of the 18th century until their expulsion. Their interest in promoting higher education and a scientific formation, which led to the founding of many universities and colleges, was clearly linked to their overall strategy of "spiritual conquest." On this issue Steger has pointed out:

"The fundamental difference of the Jesuit educational system with regards to the earlier situation lays in the fact that ... the scientific formation was not considered - as in the humanist epoch - a value in itself, but rather a weapon of the missionary crusade against heretics and pagans" (56).

The Jesuits soon obtained a monopoly of college education, which anteceded the entrance to the university. In this way they were able to control the access to the university system, as well as to influence the disciplines that were taught and the teaching methods used. The fact that they were removed from the centre of power in Spain allowed for some latitude in gaining access to the works of contemporary European scientists outside Spain. Referring to the Jesuit College of San Pablo in Lima, which controlled the access to the Universidad de San Marcos and was the Latin American Jesuit centre for the distribution of books, Martin points out:

"The scientific interest of the Jesuits of San Pablo was not limited to economics, agriculture, geography and astronomy. In the faraway and sleepy colonial city there was a group of men interested and informed on the latest scientific developments taking place in Europe ...Newton's 'Opera Omnia' rested on the shelves of San Pablo's library ...the Jesuits of San Pablo received and read ...French publications (of the Academie des Sciences) ...were also aware of the existence and activities of the Akademie der Wissenschaften which had functioned in Berlin since 1711 under the presidency of Gottfried Wilheim von Leibniz ...The scientifically bent reader also had at his disposal fifty-eight volumes in Italian of a work entitled 'New Collection of Scientific Pamphlets' ...

"The Jesuits of San Pablo had more than speculative interest in science and by the middle of the 18th century they had formed in the back room of their library a small scientific laboratory. They were able to test, in 'mathematical and physical machines' imported from Europe, the new scientific theories" (57).

This indicates that there were a few centres of intellectual activity that were trying to keep abreast of the new developments in Europe. However, the animosity between Jesuits and university authorities and the subordination of scientific to spiritual interests prevented these religious nuclei from expanding throughout colonial society.

The founding of universities in Spanish America was a key factor in the development and preservation of some sort of scientific and intellectual tradition, although at a later period, during the 19th century, it became a bastion of conservative and backward ideas. It has been pointed out that the foundation of universities in Spanish America shortly after the conquest was not a predictable and natural event (58), and that their implantation responded to a variety of pressures by the Spanish immigrants on the new colonies. The foundation of universities played a most important role in fostering and maintaining the European intellectual tradition during the first 2 centuries of the colonial period. According to Konetzke:

"The reasons for the transplantation of the European university to the New World arise essentially from the configuration and the needs of the colonial life itself. Among the eclesiastic and laic circles of the Spanish population of America there was a proven desire to possess their own higher education establishments" (59).

The university system in Spanish America suffered a series of transformations during the colonial period, but because of religious domination, among other factors, was incapable of becoming the type of intellectual centre that would spread and further develop the new scientific ideas emerging in Europe. Nevertheless, the university was instrumental in spreading the ideas associated with the Enlightenment, particularly after the Jesuits lost their dominant position in the higher-education system. The situation was rather different in Brazil, for no universities were founded by the Portuguese until the 19th century, and the University of Coimbra remained the main intellectual centre of the Lusitanian world.

The Enlightenment reached Spanish and Portuguese America in the second half of the 18th century with explosive force. The changes initiated by Bourbon administrators opened the doors to new ideas in both Spain and its colonies. The Spanish dominions tried to catch up with European science, and in Lima, for example, the Viceroy approved a new study plan in 1771 that included the teachings of Leibniz, Bacon, Gassendi, and Descartes (60). Copernican ideas were introduced into Bogota at about the same time, and throughout Latin America the universities began a transformation that changed the traditional dominance of theology and philosophy and that introduced a "scientific" outlook in the teaching of disciplines such as botany, medicine, and the physical sciences (61). The degree to which this process of catching up with Europe had succeeded toward the end of the 18th century has been emphasized by Lanning:

"The truth is that instead of a cultural lag of three centuries behind Europe there was a hiatus in the Spanish colonies of approximately one generation from European innovator to American academician. Even the case for the constant and general lag of one generation from the backward universities of Europe and the quiescent ones of America, however, cannot be successfully made out as the year 1800 approached. Indeed, as the 18th century passed, the gap became less and less ...Between 1780 and 1800, with fair allowance for transportation and isolation, the lag ceased to exist ...In reality, then, the Americans did not so much receive the Enlightenment; they reproduced it from the sources upon which its exponents in Europe depended" (62).

Even though both Lanning and Arciniegas point out that there were some antecedents to the Enlightenment in America, inspired primarily by the French, and that developments had taken place at a very rapid pace, the main thrust for advance came from abroad, and intellectual progress did not spread widely through society. The statement by Safford for Colombia may be taken as representative of the general scientific situation in Latin America in the preindependence decades:

"The initial impetus for introducing scientific and technical orientations came from abroad. Spanish Bourbon administrators encouraged scientific and technical instruction while European scientists, coming to investigate the natural phenomena of the country, aroused an interest in science among a few of the native born. By the last two decades of the colonial period a handful of creoles, with royal encouragement, were actively engaged in scientific research - particularly in gathering data about their environment - and in the diffusion of modern scientific knowledge in their society" (63).

The shock provided to Spain by the French revolution brought attempts to curtail the flow of revolutionary ideas, associated with the Enlightenment, to America. However, independence was at hand for the Spanish colonies in America, and it was too late for these attempts to succeed. Nevertheless, even though the flow of scientific ideas was not reduced significantly and the French and British gained new intellectual influence in the Americas, the turmoil of the independence wars proved to be too disturbing for the incipient and newly developing scientific community. Lanning contends that "the Enlightenment which was well underway in America a half century before the wars of independence broke out, instead of being accelerated by those wars, was actually set back in many respects twenty to thirty years" (64). Safford is more explicit on this for Colombia:

"The trauma and triumph of Independence, however, aborted the development of a native scientific and technical elite. In the nineteenth century, scientific activity received formal approval but had no real institutional support. Political instability robbed the republic of the resources needed to support research or significant scientific instruction. Few individuals could pursue scientific careers, and they lacked the reinforcement of a community of peers" (65).

The Enlightenment and the wars of independence also affected the structure of the university system. Steger (66) has suggested that in urban areas a radical version of the Enlightenment predominated, derived mainly from the works of the encyclopedists, whereas in rural areas a conservative version of the Enlightenment, associated with the ideas of Rousseau, had greater influence. These two currents would coexist for most of the postindependence period, and their interaction and struggle would have a significant influence on shaping Latin American society. This division could be clearly noticed in the university sphere as well. The first current would be associated with the secular "national" universities, having an international outlook, whereas the second would be associated with the catholic universities that had more of an American outlook.

The situation was rather different in Brazil, because there the Enlightenment had arrived in the second half of the 18th century through the efforts of the Marquis of Pombal, who expelled the Jesuits and initiated a thorough reform of the educational system. A scientific society was founded in the 1770s, a small botanical garden was started, and a few scientific experiments were carried out. The transfer of the Royal Court of Portugal from Lisbon to Rio de Janeiro in 1808 would lead to a profound transformation of Brazilian society and would provide a renewed stimulus for the pursuit of literary and scientific endeavours (67).

The first third to one-half of the 19th century, comprising the first few decades after independence, was full of internal strife, political instability, and economic difficulties for the new nations of Latin America. Among other upheavals in Latin America, fights between "centralistas" and "federalistas" in Mexico, the social and intellectual advances and retreats in Argentina during the time of Rivadavia and Rosas respectively, the internal conflicts in Peru, which led to the Bolivian secession, and the constant struggles for power in Colombia, all conspired against the orderly and cumulative growth of scientific activities in the Latin American countries. Although, as mentioned above, the Brazilian situation was rather different, the statement of Babini for Argentina could well summarize the overall Latin American situation for this period:

"With the fall of Rosas (to whom the early decline of Argentinian science is owed) a cycle of the Argentinian cultural life is closed, a cycle whose precursory signs can be seen in the efforts of a progressive viceroy, ...but which culminates ...when a new Argentina awakens and directs its sights to the 'Enlightened Europe' with the desire to incorporate the benefits of the 'Enlightenment' and the 'progresses of knowledge,' and when for the first time the European winds bring a slight scientific current to Argentina.

"But the weakness of the effort succumbs before the adverse political conditions, and at the end of the first third of the century cultural activities decline and Argentinian scientific institutions lethargize.

"In the Argentina of that time, its two universities, its museum, its library, lay dead, inert, and while a few European naturalists wander over the land as migratory birds, a French naturalist cultivates his garden in a corner of Corrientes and an Argentinian naturalist unearths fossils in the ravines of Lujan" (68).

The second half of the 19th century saw in all of Latin America a scientific revival, which was associated with both the growing influence of positivism and the attainment of more stable economic and political conditions. The latter were, to a large extent, a reflection of the way in which Latin American economies were drawn into the expanding sphere of capitalism and found their position as suppliers of raw materials within the international division of labour that accompanied such expansion.

Positivist ideas had a substantial influence on the political and intellectual life of the Latin American nations. The various branches of positivism, which interacted and intermingled closely with each other in the European continent, were introduced into several Latin American countries and were adapted to the prevailing local conditions, although there was little contact among them afterward. Positivism changed ways of thinking in religion, education, politics, and even philosophy, and it also had great influence on the development of applied sciences.

Considering the state of relative scientific backwardness in Latin America during the first half of the 19th century, it is not surprising that positivist ideas preceded the development of experimental science. Ardao has pointed out:

"The main difference between Latin American positivism as a whole and European positivism, also as a whole, was that Latin American positivism anticipated and precipitated scientific culture, instead of resulting from scientific thought as in Europe.

"In Europe positivism evolved as a philosophy of scientism. It developed as a reaction against philosophy, as a consequence of the historical victory of the natural positive sciences ...

"Positivism, from Saint Simon to Comte, became an established doctrine in the first half of the XIXth century when scientific theory developed a high historical perspective and when the practical application of scientific processes multiplied during the industrial revolution ...

"In Latin America the process was just the reverse. Scientific positivism did not originate from science; it was science that evolved from scientific experience, thus furnishing a model from which we could draw when attempting to establish science in Latin America with the help of positivism as an ideological tool.

"When positivist doctrines started to reach Latin America in the second half of the XIX century, there was almost a complete lack of scientific culture in our countries, in the sense of experimental physical-mathematical knowledge. Therefore, positivist doctrines went beyond mere acquisition of new knowledge; they involved the adoption of a new methodology, that of the natural sciences. The sponsors of positivism started by preaching the introduction of those sciences and their teaching in our cultural centres, which were then under the influence of romantic rhetoric superimposed on neoclassicism without any contradiction in the traditional metaphysical mentality" (69).

The influence of positivism on politics can be clearly seen in the case of Mexico. The political reforms introduced in the 1860s and continued for several decades were closely related to the positivist movement. Gortari (70) has linked the development of positivist ideas with the emergence of capitalism and has shown the way these were inserted into the Mexican setting and the part they played in various political conflicts. Positivism was considered "an invaluable instrument for the maintenance of order" and the Liberal Party found in the implantation of positivism a way of substituting the church, but without altering fundamentally the existing social stratification. In this way positivism had a curious dual impact on Mexican society. On the one hand, it provided the local emerging bourgeoisie with the ideological apparatus to replace the church and instaurate its own conservative social order. Thus, according to Gortari (71) the Mexican bourgeoisie "tried to impose blind obedience to the dictates of science, whose usufruct was given, as a monopoly, to a privileged minority, at the service of the political and economic regime and, for that, attempts were made to extend instruction to all social classes." On the other hand, as he has also pointed out, "it is undoubtable that the positivist reform gave a formidable impulse to education and that, at the same time, it finally established in Mexico the elementary conditions for the cultivation of modern science."

However, as the century progressed and drew near its end, the Liberals, who had espoused the introduction of positivist ideas in Mexico and had used them as the basis for their political credo, became more entrenched in the governmental apparatus and became increasingly backward in their social outlook. This affected the educational system and led to the decline of science, to the point that Gortari could state:

"In 1900, science, which had been without any doubt one of the elements involved in the program of the Liberal Reform in Mexico, was reduced to a dead subject and was employed as a magical element within the policies of the so-called scientific party" (72).

Thus in 40 years the followers of positivism in Mexico managed to turn around full circle and revert almost to the initial situation, but this time with the "help" of scientific ideas. This generated a violent reaction against the "Scientific Party" and, indirectly, against scientific ideas, even though the inheritors of the Liberal Reform had long since abandoned the basic principles of positivism and had reduced the teaching of scientific ideas to mere formal exercises.

Positivism also spread to Argentina, Brazil, Central America, Uruguay, Chile, and Peru (73), although its influence was more marked in Argentina, Brazil, and Mexico. During the same period that positivism began to spread, the university system in Latin America underwent major transformations and became what Steger (74) has called a "lawyers university," emphasizing professional training.

The closing of the 19th century saw a rather mixed picture with regard to the state of scientific endeavours in Latin America. They had been stimulated by positivist ideas and by the increased demand for technical inputs arising from the expanding economies and the incipient growth of industries. However, problems of a political, economic, and institutional nature, such as those described above for Mexico, impeded the full development of a cumulative scientific tradition. For example, in Argentina, after 3 decades of significant achievements in science between 1860 and 1890, a period of decline in pure science followed, while in the technical and economic fields substantial advances were registered. The contrast between a stagnating science and a flourishing technology constituted the "crisis of the 1890s" in Argentinian science. According to Babini:

"...(this crisis) put in evidence how utilitarian pursuits and material interests accompanied by a growing immigration wave, made technical and economic activities prevail and absorb intellectual activities, postponing the concern for pure science and blocking any initiative in favor of disinterested research.

"This led to the error of adopting and absorbing the applications of science before science itself, without realizing that behind the exciting splendour of industrial and technical progress lies hidden the disinterested and pure work, which contributed decisively to that progress" (75).

The state of scientific and technical dependency of Latin America was rather significant and can be best exemplified by referring to the Colombian situation in the 1880s, whose features remained essentially unchanged until the end of the century. Safford has pointed out:

"Until the 1880s Colombia stood in an unequivocally colonial relationship to Western scientific centres. All of its scientific and technical ideas originated abroad, and many of its science instructors and engineers were either foreigners or trained in

Europe and the United States. There existed almost nothing in the way of institutional support for indigenous scientific and technical activity. After 1880 Colombia's technical dependency remained quite evident, but technically trained Colombians were beginning to move towards at least a marginal autonomy" (76).

The situation in Brazil, which had enjoyed a more continuous process of institutional development throughout the 19th century, was representative of a country that had reached a higher stage in the development of scientific activities, and has been characterized by Steppan as follows:

"...by 1900 the number of institutions of science, though still small, was on the increase, and the facilities of several of them had been improved. The number of foreign scientists working in Brazil, many of them on contract to the government, had also increased, and they spurred a more disinterested pursuit of science ...Opportunities for careers in science were slowly increasing, especially in medicine and engineering.

"Nonetheless, despite this 'awakening' ...the scientific establishment was small and no part of Brazil's educational or scientific structure was capable of producing or training research scientists in a systematic fashion. Originality in science was still a result of individual effort, European training, and, often private wealth ...The institutionalization of scientific values was far from complete, especially in the government bureaucracies administering scientific institutions" (77).

In Peru and Venezuela there were just a few individuals doing research almost in isolation, although engineering schools had been founded and the physical and engineering sciences were being increasingly taught and practiced.

The conditions that the pursuit of science faced at the end of the 19th century, and the awareness of these in Latin America, can be best exemplified by quoting an editorial from the journal "Anales de Ingeniería" of Colombia, published in September 1894:

"Today our science is of an imitative and data-gathering nature; we learn and repeat what others have thought or done, but we do not inquire on our own; it is to this lack of originality in aspirations and methods that we undoubtedly owe our weakness. With propitious conditions for the development of scientific aspirations we remain, however, inactive.

"What are we waiting for? That others come to solve our scientific problems, as we expect them to come and solve our industrial difficulties?

"Even if...our scientific activity is still very restricted, this should not be a motive to discourage us; on the contrary, it should be a stimulating cause to march ahead: 'Fac et spera' is a good motto for the workers of the mind" (pp. 258-259).

The introduction of Western science into India during the 19th century also faced many problems, although these were of a kind rather different from those of Latin America. India remained under British rule throughout the 19th century and half of the 20th century, and the introduction of science continued to be conditioned by British colonialism.

During the first half of the 19th century the practice of traditional intellectual activities diminished sharply in India, and Sen (78) mentions the efforts of British scientists and intellectuals to recuperate traditional knowledge in areas such as astronomy and medicine. These efforts were not always successful, because it was difficult to find men who continued to carry on the intellectual traditions of earlier times. As Sen points out: "The general loss of interest in, as also the decay of, mathematics, astronomy, and other branches of science in the oriental sector of learning (were) clearly manifest" (79).

The teaching of Western mathematics, physics, and geography was more or less generalized throughout the Indian colleges by 1841, and British textbooks were being used in most of these subjects, covering topics such as algebra, geometry, integral and differential calculus, spherical trigonometry, mechanics, hydrostatics, pneumatics, and optics. Medical studies also developed with the establishment of institutions such as the School for Native Doctors and with the beginning of medical education in some of the Sanskrit colleges. With the advent of medical studies, chemistry, botany, and natural philosophy also received increased support.

The Educational Despatch Act of 1854 led to the creation of new institutions and the expansion of existing ones. The objectives of the Despatch were to promote "the diffusion of the improved arts, science, philosophy and literature of Europe; in short of European Knowledge." This led to the creation of five new universities in the period from 1857 to 1902, and the growth of colleges from 27 in 1857 to 75 in 1882 and 126 in 1902.

However, the Educational Despatch Act of 1854 was not followed by significant developments in scientific education and research, and this was attributed to the non-teaching character of the universities established in this period, as well as to the failure to appoint university professorships as recommended by the Despatch.

While these developments were taking place in the educational sphere, government departments in charge of performing scientific and technological activities were systematically excluding Indians from senior posts. This was particularly the case in the Geological Survey of India, where the first Indian apprentice was recruited only in 1873, almost 25 years after it was founded, and the first appointment of an Indian to a graded post did not take place until 1880. Sen has indicated:

"...the Indians were excluded, as a matter of policy, from participation in the Government scientific undertakings through the various surveys and departments, ...and the exciting work of a century by many able minds was largely lost on the people" (80).

This policy of exclusion continued into the 20th century and was also reflected in the differential salary levels earned by Europeans and Indians in a variety of institutions, ranging from the Botanical Survey and the Agricultural Service to the Meteorological Department and the Indian Trigonometrical Survey.

Several scientific societies were founded in India during the 19th century, and these were instrumental in promoting the growth of scientific activities. The Asian Society, founded in 1784, was the forerunner of all these associations. The Agricultural Society was founded in the 1820s, the Madras Literary Society was started in 1833, the Indian Association for the Cultivation of Science was founded in 1876 and soon became one of the most important scientific institutions, the Bombay Natural History Society was founded in 1883, and several other such organizations followed in the early 1900s.

Thus by the beginning of the 20th century a viable minimum scientific infrastructure in science and technology had come into existence in India. It has been noted that the creation of such an infrastructure was the result of determined efforts by the Indians themselves, and to this effect Sen cites the example of Mahendra Lal Sircar, whose efforts led to the foundation of the Indian Association for the Cultivation of Science. According to Sen:

"...science returned to India largely as a consequence of the movement for national self-determination. Its return was delayed to the extent this movement for self-determination was delayed. As soon as this vital social role of science is realized it is futile to expect its appearance in a colonial type of administration dominated by one-sided commerical preferences and characterized by its fundamentally negative attitude to all developmental programmes. In such a situation field sciences may be developed as administrative convenience and necessity by imported scientists, but not basic laboratory science in universities and institutions open to the people for their fullest participation" (81).

Nevertheless, even though the definite introduction of Western science into the Indian scene may have been associated with self-determination movements, the fact that modern science was associated with the image of the British rulers played a part in hindering its acceptance. Rahman (82) suggests that the introduction of modern science in India had three limitations: the fact that it was geared to the needs of the British rulers; the emphasis on teaching results rather than on creating an appreciation of science as a tool for intellectual and social transformation; and the fact that it was introduced in English. The consequence was as follows:

"...instead of playing the role it did in Europe it (science) became isolated. It did not react with the different strata of society and people, but leaned heavily for its growth on the government and became an intrinsic part of the policies of the rulers.

"By virtue of its association with the rulers, and by becoming an instrument of their policies, science became suspect in the eyes of the nationalists. Instead of using science as a weapon in their fight for emancipation and social transformation, they shunned it and leaned back heavily on social outlooks, philosophies and values of the earlier period" (83).

In Egypt the 19th century witnessed the first determined efforts to introduce Western culture and science. Shortly after the withdrawal of Napoleon's army from Egypt, Muhammad Ali assumed power and began the first large-scale efforts to modernize the economy and expand the educational system, with the assistance of European advisors and teachers. Under his rule the schools of medicine, pharmacy, engineering, agriculture, and veterinary medicine were founded in the 1820s and 1830s. He also sent several hundred Egyptian students to Europe in an effort to prepare a local elite trained in the Western modes. Muhammad Ali also strengthened the army, founded a school of military science, and sought to establish an industrial base to support the requirements of its armed forces, while devoting himself to increasing the cultivated land.

The modernizing efforts of Muhammad Ali - which were carried out under his personal direction and allowed him to protect Egypt from some of the most disruptive clauses of the capitulations that had already destroyed the industrial base of other Arab regions - were soon brought to a halt after 1840, when he relinquished power. The rulers who followed him did not have the same energy and vision, and the economic mismanagement of the Khedive Ismail placed Egypt's economy under foreign control, which was followed by British occupation in 1882. Therefore, in spite of the impressive efforts made during the first half of the 19th century by Muhammad Ali, at the close of the century Egypt was under British occupation and the modernizing reforms had lapsed into oblivion (84).

The higher-education system, which by the 1900s comprised the Law School founded in 1868, a school for the training of teachers of Arabic (1872), the Higher Teacher's College (1880), the School of Islamic Law (1907), and the School of Commerce (1911), in addition to those founded earlier, was in frank decline. According to Akrawi:

"Many of these 19th century schools often lapsed into a deplorable state. Some were closed once or twice, only to be reopened because of need. Although they generally came under the jurisdiction of the Ministry of Education, they did not constitute a university but were run individually. Moreover, the number of students in them was limited; the six schools existing in 1892 had a total of 229 students" (85).

The lack of facilities for students, the tight control of the British occupying forces over Egyptian finances, and the inadequate provisions for education led a group of Egyptian leaders to found a private secular university in 1908. This was later absorbed into the National University, which was founded after independence was declared in 1922, and which by 1925 had taken over most of the existing colleges.

In parallel with the efforts to establish a minimum educational infrastructure that would help in the introduction of Western culture, Arab intellectuals were going through a period of critical appraisal of Islamic culture and were attempting to understand Western ideas and adapt them to their own situation. Ibrahim has noted:

"Egyptians in the late 19th century became aware of the maladies in their own society and civilization; they recognized the superiority of Western civilization to their own and were convinced that the only way to resurrection was the assimilation of Western civilization, in particular its scientific spirit. Once this has been achieved, the revival of Islamic state and society would follow.

"For the intellectuals of that time, Moslems and Christians alike, Islamic civilization was in decline and could not help society to progress. It was Europe which had reached the highest state of development and this was because it had recognized the role of science and had made it the basis of its thought and action. Nahda ('resurrection') therefore could not be accomplished without the assimilation of the sciences which formed the basis of Europe's technological superiority" (86).

The Lebanese took the lead in expounding the new ideas that were being discussed in the second half of the 19th century in Europe, including evolution and positivism. This led to a questioning of the religious outlook and of the literary tradition prevailing in Islamic culture. Writers like Musa emphasized that differences between East and West were due to differences in culture, tradition, and outlook, but also pointed out that these were neither hereditary nor inherent in the nature of East and West - they were merely acquired and could be changed. According to Ibrahim, Musa believed:

"...dynamic modern European civilization and thought had grown out of the scientific industrial system, just as the traditional stagnant and corrupt Eastern civilization grew out of agricultural society.

"Musa therefore urges the East to adopt the sciences of Europe and develop a national industry. Once this has been achieved, its ethical system and cultural outlook will become those of Europe: it will have a culture based on science, freedom of women, democracy and a parliamentary system" (87).

Musa's ideas, which also contained a profound questioning of religious values, were shared by other writers such as Ismail Mazhar, who was influenced by the positivist ideas of Comte and by evolutionary theory. According to Ibrahim's interpretation, Mäzhar considered science and systematic thinking as superior to literary and metaphysical abstraction. This implied that Arabo-Islamic civilization remained limited to the second or metaphysical stage of Comte's scheme and thus could not develop and reach the third or positivist stage; hence the absence of scientific or philosophical thought in Islam. Mazhar also attacks the fatalistic and impractical character of the Eastern mentality, seeing it as incapable of apprehending and confronting modern civilization and its problems.

Writers such as Musa and Mazhar represented a "radical" school of thought in their rejection of Eastern and their acceptance of Western culture. However, many other Arab thinkers, particularly those of the interwar period in the 20th century, did not share these radical views and advocated a blending of Eastern and Western outlooks. Ahmad Amin is one such writer, and although he acknowledges that the influence of Western science has become irresistible and the East has become linked to the West in all aspects of life, he still maintains it is possible to preserve the individuality of Islamic civilization. Ibrahim interprets Amin's ideas in the following way:

"What the East lacks and needs to adopt from the West is science. It could be maintained (Amin argues) that Islamic civilization is diametrically opposed to Western civilization, in that the former is characterized by its spirituality and human outlook, whereas the other is rational and materialistic. This is true; nevertheless, a reconciliation between both is possible, because Western civilization does not rest on religion. Were it based on a religion which opposed Islam, any assimilation would become impossible ...'but fortunately that is not the case ...it does not rest on religion but on science.' Hence there is no objection to borrowing from it, 'indeed it is their (Moslems') duty to adopt Western science,' without which there could be no happy life" (88).

Thus Egypt, and the Middle East in general, were struggling in the late 19th and the early 20th century to come to terms with the scientific ideas developed in Western Europe and were seeking ways of harmonizing them with the traditional patterns of Islamic thought. These efforts, together with the institutionalization of higher education, led to the beginnings of scientific activities in the first half of the 20th century.

In Korea, which remained under Japanese rule between 1910 and 1945, the introduction of Western ideas was filtered by the Japanese and remained under their firm control. The educational system began to expand; in 1924 the first modern university was founded and the first college of engineering was set up in 1938. Opportunities for Koreans were, however, severely restricted by a quota system that maintained a strict ratio of Korean to Japanese students. As a result, by 1945 only 800 Koreans had university degrees, of which about 300 were from the Medical School and approximately 40 from the School of Science and Engineering.

The social upheavals and the stormy history of Macedonia prevented it from developing a scientific tradition of its own, even during the 20th century. There were no organized or institutional forms of scientific research in Macedonia during the period preceding World War II. Whatever existed was the result of individual and isolated efforts and was destroyed by the war. Furthermore, most of these early attempts were directed at reaffirming Macedonian cultural identity, and science became a part of such efforts only after World War II.

After this brief review of the way in which Western science was introduced into the STPI countries, it is possible to offer some general remarks on the state of science and technology at the end of the 19th and the beginning of the 20th century, just before the drive toward industrialization began. At that time, in none of the STPI countries had the pursuit of science developed into a well-established activity, enjoying the full support of government institutions and making significant contributions to world knowledge. This was the result of many complex factors, which impeded the cumulative development of a scientific tradition and did not create a favourable environment for the cultivation of science.

The first of these factors is the lack of social demand for science, as there was no inducement for the ablest minds to embark on scientific and technological pursuits. This was a consequence of the incipient level of economic development, which did not create a sustained demand for local scientific and technological inputs, and of the fact that the intellectual and technological superiority of the West made it the logical source of ideas and productive techniques. The motivation to do science because of the material well-being that might be derived from it was absent until the 20th century in all the countries examined. In India, in contrast with Latin America and to a lesser extent Egypt, the colonial power was clearly aware of the importance of science for the consolidation of its position, and hence some kind of "social demand" for science may be thought to have arisen during British rule in India. However, this demand was directed at the reinforcement of colonial conditions, and Indians were systematically excluded from the performance of scientific activities.

A second factor lies in the values and attitudes that do not foster a favourable environment for the pursuit of science. The Spanish and Portuguese cultural traits that were transplanted into Latin America and the Islamic values predominating in Egypt are two examples of this. Fatalism, and the feeling of futility of worldly matters, associated with a deep religious outlook, act as effective deterrents to the building up of a scientific tradition (89).

Given that science, and the technology that relates to it, require a rather long time to develop, a third factor that has weighed against the growth of an indigenous scientific tradition has been the political and economic instability of the STPI countries. This was particularly the case in Latin America and Egypt, where determined efforts lasting several years, and even decades, were undermined and suffocated in later periods.

Finally, the pursuit of scientific activities must be preceded by the development of a cultural identity and a perception of the legitimacy of one's civilization. This has been a problem for Macedonia and Korea, both of which suffered foreign dominations that suppressed their own culture for long periods. To a lesser extent this was also the case in India and Egypt.

Thus at the time that modern industry, and the science and technology that accompany it, began to penetrate the economies and societies of the STPI countries, the setting was not the most propitious for absorbing the new developments of industrial science and technology and for internalizing the social values associated with them. The pursuit of science had not developed roots and could not provide a basis for the adaptation and further improvement of the industrial techniques introduced at the time. The insertion of these techniques into the economy of the STPI countries would be stepped up during the first half of the 20th century.

Notes on the Emergence of Industry-Related Science in STPI Countries

The evolution of science and technology in the STPI countries during the 20th century followed a more regular path and was closely tied to the growth of industry, at least in the part that is of concern to the subject matter of the STPI project. The efforts made to industrialize began to create a demand for scientific and technological activities, particularly those of an applied and service nature.

The development of the engineering profession in STPI countries was largely a result of the pressure exerted by the expansion of infrastructure works and the development of manufacturing activities, which began in the late 19th century but whose full development would wait until the 20th century.

The construction of railroads in Latin America constitutes a good example of the opportunities and the limitations that the development of infrastructure works and of manufacturing presented for the development of local science and technology. Latin America underwent a process of massive railroad construction in the last third of the 19th century, primarily under the stimulus provided by an export-oriented economic growth pattern and by the inflow of foreign funds - mainly British - that were made available for this purpose. This created a demand for local technological inputs, which was limited by a variety of factors. Felix has noted that one of the elements reducing the developmental impact of railroad building in Latin America was the limited amount of technological spillover:

"Local repair shops were established in most Latin American countries, but rails, rolling stock and most ancillary equipment continued to be imported ...The same was also true of other infrastructure technology imported on the heels of export bonanzas: tugs, port loading equipment, ships and ship repair facilities, gas works, tram lines, telegraph systems, electric generation and transmission systems, ...much of the ownership was foreign ...(and) the import content of these infrastructural activities declined very slowly" (90).

Among the factors that contributed to this limited technological spillover, Felix also identified the "maturity and relative standardization of the infrastructure technologies and their embedment overseas in well-developed equipment and supply networks, design procedures and construction firms with ample access to the financial markets of the advanced countries by the time they began to be disseminated to Latin America" (91). Furthermore, the tying arrangements between the foreign-run construction firms in Latin America and the manufacturers and suppliers of equipment overseas also limited the possibility of using local technical inputs. However, these tying arrangements and the high import content of infrastructural works would not have endured for so long - lasting well into the 20th century - were it not for the deficient base of local entrepreneurial and industrial skills and the difficulties that entrepreneurs encountered in moving toward the manufacture of relatively more sophisticated equipment and machinery.

Although there are a few examples of notable local entrepreneurial and technological skills in a few Latin American countries throughout the 19th and the beginning of the 20th century (92), the incipient industrial base that existed, mostly of an artisan nature, was not capable of transforming itself into a modern industrial sector and generating a sustained demand for local scientific and technological activities. The initial artisan base was broadly divided into a native crafts sector and a "modern" monetized sector. With regard to the former Felix adds:

"...(it) was too distant from European technological and institutional modes to have been a fertile seedbed for technological spillovers. Careful nurturing through enlightened state policies might have changed this but (1860 to 1920) policies continued instead the practice of treating the Indian villages primarily as sources of agricultural and mining labour ...The result was the degeneration of Indian crafts rather than the progressive linking of Indian with European artisan skills" (93).

The "modern" artisan sector was primarily oriented to supplying implements for mining, agriculture, construction, and road transport, as well as consumer goods and durables such as processed food, textiles, furniture, leather goods, and kitchenware for the segment of the population linked to the export and service activities. Because of their low quality:

"...'modern' artisan products were very vulnerable to the rapidly rising import competition from cheaper factory products....The flood of competitive imports proved too great to enable the local artisanry to adapt through learning adjustments. Adaptation required continual technological and organizational improvements, for which a necessary condition was an adequate rate of capital accumulation and external credits to finance the improvements. Artisanry, however, was left largely to shift for itself, which meant cutting prices and sweating labour in an effort to survive. The vicious circle of declining profits, poor credit risk, inability to finance improvements, and inability to upgrade quality and productivity thus led to the decay of many artisan lines" (94).

Safford (95) has confirmed these observations by pointing out the inability of the Colombian artisan sector to transform itself and become the basis for modern industry, while he also emphasizes the disrupting effect of imports from the European nations.

The new industrial activities that were started and the expansion of older activities such as mining provided employment opportunities for the graduates of the newly founded engineering schools. However, as the scale of operations expanded, many of the productive activities that were started by local entrepreneurs and technicians were transferred to foreign owners. This can be clearly seen in the case of mining:

"...native capital pioneering in the early expansion of mineral exporting (was) almost totally displaced later by large-scale foreign enterprises. Mining in many of the 'Cordillera' countries had been the core of the export sector during the colonial era, and around it had developed a largely indigenous set of skills, technology and supplier networks....As world demand expanded, freight costs fell, and overseas mining technology advanced, Latin America came to be a prime region for foreign mining investment, so that by the eve of World War I export mining had become overwhelmingly a foreign controlled activity. With the transition, input linkages with the host economy were progressively reduced. The new technologies were heavily labour saving, depended on foreign equipment, fuels and technical and supervisory personnel, transferred profits to foreign owners, and paid minimal local taxes" (96).

Similar situations were to be found in Argentina at the time the local "saladeros" (salting houses) were replaced by the "frigorificos" (cold storage plants and ships) in the processing and export of meat. The former, based on locally developed technology, could not adapt and move to the new processes, and this led to the dominance of foreign enterprises.

The expansion of engineering schools throughout most of Latin America at the beginning of the 20th century (97), the founding of engineering societies (which began to press for greater local participation in investment projects), and the increased demand for technical services led to the establishment of a few centres of industry-related scientific and technological activities. In parallel, the university system underwent some changes - particularly after the 1918 reforms initiated in Cordoba, Argentina - and governments began to pay more attention to technical issues as the efforts to industrialize took form.

Import substitution industrialization shaped the subsequent growth of industry-related science and technology. Sanchez Crespo (98) has pointed out the close interconnection between the technical difficulties faced by industry at various stages of the import substitution process and the appearance of institutions in charge of performing the scientific and technological activities required to solve them. Thus, for example, once the first determined impulse toward import substitution began, it became necessary to standardize the manufacturing of a variety of products. The import of machinery and equipment from the United States and European countries led to a proliferation of technical norms and standards and hindered the orderly growth of industry and the linkages among various industrial branches. Technical norms and standards institutes were founded in Argentina in 1935, in Brazil in 1937, and in Mexico in 1945. In Colombia, Venezuela, and Peru, which lagged behind the three largest Latin American countries in their industrialization, standardization institutes were not established until the late 1950s and the early 1960s.

The difficulties encountered by the import substitution process when a saturation point was reached in the production of consumer goods, and when efforts were made to move toward the manufacture of capital and intermediate goods, brought a new concern to the Latin American industrial sector: improving productivity. Both the government and private sectors created organizations to increase productivity and these spread rather fast throughout Latin America, often under the stimulus of foreign assistance. In Argentina the National Productivity Institute was founded in 1957 and the private Argentinian Productivity Association in 1959. In Brazil two such institutions were founded in the 1958-1960 period, and in Colombia, Mexico, Peru, and Venezuela these appeared in the 1955-1960 period. Initially, the productivity movement was more closely associated with improvements in organization and administration, while the concern for technological matters was left somewhat aside.

Although the founding of the Industrial Technology Institute took place in Brazil in the 1930s, such institutions appeared in most of the other countries under study in the 1950s. Thus Mexico established its Industrial Technology Institute in 1950, Argentina in 1957, Colombia and Venezuela in 1958, and Peru also in the late 1950s. However, the participation of these institutions in industrial activities was fairly limited until the mid-1960s, when the concern for technological issues began to spread throughout Latin America. All of these organizations undertake primarily applied industrial research, usually adaptations of imported technologies, and they also provide specialized services to industry.

The difficulties involved in the development of indigenous capabilities for science and technology in Latin America during the second half of the 19th century and the first two-thirds of the 20th century have been clearly summarized by Felix. He divides the 1860 to 1970 span into two periods, the first of which runs from the 1860s to the 1920s and the second from the 1920s to the 1970s. This division is justified in terms of the major shifts in trade and domestic policies, which were marked by the Great Depression, and also because the conditions for doing industrial science had changed dramatically: the main sources of innovation shifted from empiricist tinkering and learning by doing to organized science and technology efforts. According to Felix:

"...Latin American countries, although eager borrowers of imported technologies, have been institutionally out of phase in both periods, each time for a somewhat different set of reasons, for creatively adapting and diffusing advanced technologies on a broad enough scale to become progressive monistic economies. In Period I when most of the knowledge, risk and capital requirements for adapting and diffusing new technology were still within the capabilities of alert artisans and individual entrepreneurs, Latin American countries were deficient in both. Out of the painful import substitution industrialization efforts of Period II, an adequate base has emerged, at least in the more industrialized Latin American countries, for effectively elaborating upon and diffusing nineteenth century technology. But technology has also moved on, and the institutional requirements for broad-scale diffusion of mid-twentieth century technology remain out of reach. Hence Latin American countries and the majority of their citizenry continue to suffer the many socioeconomic ills that result from unalloyed technological borrowing, as did their forbears two to three generations back" (99).

Industrial activities in India expanded slowly during the late 19th century and the first decade of the 20th century. The requirements of World War I and the political pressures exerted by the nationalist movement led to the appointment of a commission in 1918 for appraising the status of the existing industrial research facilities and for making recommendations for their improvement. However, as Rahman et al. (100) have pointed out, very little was done until 1935, when the government of India established the Industrial Intelligence and Research Bureau, whose aim was "making a beginning and to lay the foundation on which a research organization suitable for the needs of the country could later be constructed."

Although existing industry in the interwar period required increased local technological services, it was war again that led to an upsurge of interest in industrial research. According to the National Committee on Science and Technology:

"The outbreak of the second world war brought about a radical change in the pattern of scientific and technological research in India. The colonial government, being cut off from Britain, was forced to actively develop local resources to meet the demands of war and the then existing research institutions and universities were given considerable encouragement and research grants" (101).

By 1942 the Council of Scientific and Industrial Research had been set up and the proposals to establish a National Physical Laboratory and a National Chemical Laboratory had been accepted. A committee set up by the government at about the same time recommended that the scheme of national laboratories should be expanded to encompass specialized institutes in food technology, metallurgy, leather, roads, etc.

The main thrust to expand industry-related scientific and technological activities in India came after independence, and Nehru himself provided determined support and encouragement to the growth of science and technology. A portfolio of scientific research was created in 1947 and brought under the Prime Minister himself. The Department of Scientific Research was created in 1948, and the Council of Scientific and Industrial Research was reorganized and put under its jurisdiction. Several other organizations were created in the decade following independence, and in 1958 Nehru moved Parliament to adopt the Science Policy Resolution, which indicated the government's intent to support science and technology to "secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge" (102).

Following the Science Policy Resolution of 1958 and in close interaction with the planning process, resources for science and technology were greatly expanded, the institutional network of research organizations was enlarged, and a succession of committees was formed to define the orientation that a science and technology policy should take. For example, between 1958 and 1972 expenditures on research and development increased almost tenfold, the number of scientific and technical personnel employed in research and development establishments increased fivefold, and expenditures on research and development as a percentage of the gross domestic product more than doubled to reach 0.54%.

Industry-related scientific and technological activities in Egypt are also of recent origin. Although there was a considerable expansion of infrastructure works in the later part of the 19th century (recall the construction of the Suez canal), they did not leave any mark on the development of local engineering and technological activities. Railroad and telegraph lines were built, but because "there was a general lack of understanding of the technology that was needed to buy, install and operate these systems; reliance on foreign advisors, engineers and technicians naturally followed" (103). Thus the impact of these infrastructure works on technical development was even more limited than in Latin America.

The growth of light manufacturing industries in Egypt after World War I began to create an incipient demand for engineering and technical services. On the eve of World War II local industry satisfied a substantial part of domestic demand, and the war stimulated the growth of Egyptian industry because of shortages of most manufactured goods. Throughout the process of industrialization, which was greatly stepped up after 1956, the relationship between industrial growth and local scientific and technological research remained very weak.

The first government-sponsored body for the organization of scientific research activities was the National Research Council, established in 1948, at whose initiative the National Research Centre, a multipurpose research organization, was started in 1956. However, the dominance of foreign technology, from both Western and Eastern European countries, was not conducive to the development of close linkages between local industry and the Egyptian research establishment.

Since 1956 a variety of governmental decision bodies have been created and the responsibility for promoting scientific and technological development has shifted from one government organization to another. In addition to the limitations resulting from a lack of demand for local scientific and technological activities, institutional instability in the policymaking bodies has been one of the main limiting factors in the development of technological capabilities.

Industry-related science and technology were almost nonexistent in Korea until the 1950s and 1960s. Industrial development under Japanese occupation was concentrated in the northern part, where hydroelectric power and mineral resources were available. The southern part, with a milder climate and flatter lands, concentrated on agriculture. Thus, when Korea was divided into North and South after World War II, there was almost no heavy industry in South Korea, and in particular no electric power generating capacity. American and United Nations assistance between 1945 and 1951 supported mainly the import of consumer goods, and there was no significant industrial or technological development. The Korean war of 1950-1953 destroyed both North and South, and even small-scale industries disappeared.

For the following decade Korea depended heavily on grant-aid from the United States and the United Nations. This made little contribution to technological modernization, but it did support the training of technical personnel in foreign countries and the establishment of teaching facilities and engineering colleges in Korea. There was some development of scientific and technical manpower at that time, but little institutional growth. The first serious attempt at promoting research was the establishment of the Atomic Energy Research Institute in 1959, which, in spite of a limited output in terms of research findings, provided valuable lessons for the development of Korean science and technology.

After the shift in national policy in the 1960s, which emphasized the export of manufactured goods, came the formulation and implementation of the first and second science and technology development plans, in parallel with the corresponding economic development plans. These two plans concentrated on the development of scientific and technological manpower and on the expansion of research facilities. The Economic and Scientific Advisory Council and the Ministry of Science and Technology were established within the government structure, followed by the founding of the Korean Institute of Science and Technology in 1966, and later (1971) the Korean Advanced Institute of Science, the Korea Development Institute, and the Agency for Defence Development, which, together with the earlier-founded Korean Scientific and Technological Information Center, constituted the Science Park or "Seoul Research and Development Complex."

During the 1960s Korean industrial development was largely dependent on American loans, grants, and private financing, and on long-term foreign loans with international banking organizations. Industrial plants were imported and installed on a turn-key basis, the domestic market developed behind protective barriers, and exports consisted mainly of labour-intensive goods produced with low-cost labour. As a result the technical needs of industry were rather limited. However, considering the industrial development strategy devised for the 1970s and 1980s, the need for local scientific and technological inputs will increase significantly.

In Macedonia industry-related scientific and technological activities did not start until the second decade after World War II, when the emphasis shifted from agriculture to heavy industry. A few research centres were started around the large investment projects, particularly mineral processing, while the university began to expand its laboratories. However, the predominant influence of foreign technology has limited, in the same way as it has done in the other STPI countries, the demand for local scientific and technological activities.

NOTES

(1) See D. de Solla Price, Science since Babylon, New Haven, Yale University Press, 1965; G. Sarton, Historia de la ciencia, Buenos Aires, EUDEBA, 1965; and J.D. Bernal, Science in history, Vol. 1, Cambridge, Mass., MIT Press, 1971; these are some of the many authors who deal with the early development of science.

(2) See S.F. Mason, A history of the sciences, New York, Collier Books, 1962; Bernal, op. cit., Vol. 2; and W.C. Dampier, Historia de la ciencia, Madrid, Technos, 1972.

(3) See H. Hodges, Technology in the ancient world, Middlesex, Penguin Books, 1971, especially chap. 7; T.K. Derry and T.I. Williams, A short history of technology, London, Oxford University Press, 1970; and D. de Solla Price, op. cit., chaps. 2 and 3.

(4) H. Hodges, op. cit., p. 187.

(5) C. Singer, Science under the Roman Empire, in his book From magic to science, New York, Dover Books, 1958.

(6) Seyyed Hossein Nasr, Science and civilization in Islam, New York, New American Library, 1970. For an account of the life and work of one of the great Arab scientists, Al-Biruni, see the June 1974 issue of The UNESCO Courier.

(7) See C. Singer, The Dark Ages and the dawn of science, in his book From magic to science, New York, Dover Books, 1958; P. Rossi, Los filósofos y las máquinas 1400-1700, Barcelona, Ed. Labor, 1965; J.D. Bernal, op. cit.; and A. Crombie, Historia de la ciencia: de San Agustin a Galileo, Barcelona, Alianza Editorial, 1974.

(8) Alfred North Whitehead, Science and the modern world, First edition, 1925, The Macmillan Company; reprinted in Pelican Mentor Books, 1948, p. 13. J. Needham in chap. 8 of his book The great titration: science and society in east and west, London, Allen and Unwin, 1969, has explored this point, comparing China with Western Europe.

(9) T.K. Derry and T.I. Williams, op. cit.; S. Mason, op. cit., chap. 10; L. Mumford, Técnica y civilización, Madrid, Alianza Editorial, 1971; and L. White, Jr., Tecnología medieval y cambio social, Buenos Aires, Paidos, 1973.

(10) L. Mumford, The pentagon of power, New York, Harcourt Brace Jovanovich, 1970, pp. 140-141.

(11) On this issue see, for example, J.H. Elliot, El viejo mundo y el nuevo 1492-1650, Madrid, Alianza Editorial, 1972; I.B. Cohen, The New World as a source of science for Europe, in Proceedings of the 9th Congress of the International Historical Society, Barcelona, 1960, pp. 95-130; and K. Mendelssohn, The secret of Western domination, New York, Praeger Publishers, 1976, particularly chap. 2.

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Appendix 1
INSTITUTES AND COUNTRIES PARTICIPATING IN THE STPI PROJECT

Argentina	Secretaria Ejecutiva del Consejo Latinoamericano de Ciencias Sociales (CLACSO) Country Coordinator: Eduardo Amadeo
Brazil	Financiadora de Estudos e Projetos (FINEP) Country Coordinator: Fabio Erber (until September 1974) and José Tavares
Colombia	Fondo Colombiano de Investigaciones Cientificas y Proyectos Especiales "Francisco José de Caldas" (COLCIENCIAS) Country Coordinator: Fernando Chaparro
Egypt	Academy of Scientific Research and Technology Country Coordinator: Adel Sabet (until July 1975) and Ahmed Gamal Abdel Samie
India	National Committee on Science and Technology Country Coordinator: Anil Malhotra (until June 1975) and S.K. Subramanian (until March 1976)
South Korea	The Korea Advanced Institute of Science (KAIS) Country Coordinator: KunMo Chung
Mexico	El Colegio de Mexico Country Coordinator: Alejandro Nadal
Peru	Instituto Nacional de Planificacion (INP) Country Coordinator: Enrique Estremadoyro (until February 1975) and Fernando Otero Technical Directors: Fernando Gonzales Vigil (until February 1975) and Roberto Wangeman
Venezuela	Consejo Nacional de Investigaciones Cientificas y Tecnologicas (CONICIT) Country Coordinator: Dulce de Uzcategui (until July 1974) and Ignacio Avalos
Yugoslavia (Macedonia)	Faculty of Economics, University of Skopje Country Coordinator: Nikola Kljusev

Appendix 2
SURVEY OF THE COUNTRY TEAM'S WORK

The organization, composition, and orientation of each of the country teams reflected the own interests and those of the institutions that hosted them, always within the framework of the STPI project concerns. A brief review of the approach and the work of each team may help to place the STPI project and the comparative reports in perspective. To complete the survey, a description of the field coordinator's office work is given.

ARGENTINA: The initial location for the Argentine team was the Department of Economics of the Catholic University. However, after some months, the university decided to withdraw its application and the country coordinator moved to the Argentine branch of the executive secretariat of the Latin American Social Science Council (CLACSO). The team was headed by Eduardo Amadeo, an economist, and two other members were appointed to work full time on the project. An advisory committee of several researchers and policymakers active in science and technology policy was formed. To carry out the research, the team relied on consultants who wrote reports on specific subjects that were integrated into a final report.

A significant change took place when the country coordinator was named president of the Instituto Nacional de Tecnologia Industrial (INTI), the national industrial technology institute, which is the largest and most important industrial research organization in Argentina. Mr Amadeo never relinquished his formal role as coordinator; after 6 months, he left his new post and resumed his position as country coordinator. Because most of the work was well under way, his absence did not substantially alter the team's pace, although the preparation of the Argentine synthesis report was postponed. Part of the team's work was reoriented to be most useful to the coordinator in his new position.

The Argentines focused on two branches of industry - machine tools and petrochemicals - but studied many broader issues. For instance, the reports include a document on the technological content of the 3-year development plan (1974-77), a study of the Argentine industrial structure, a description and brief analysis of technology policy instruments in Argentina, a study of the system for regulating technology imports, and several short reports on international technical assistance as an instrument of technology policy.

The structure of the Argentine scientific and technological system was studied in detail, as were the conditions under which it could be made more responsive to industry's needs. The Argentines covered the public sector, examining the possible rôle of the public sector as promoter of scientific and technological development. Detailed studies were carried out at two enterprises: one in charge of generating electricity in Buenos Aires (SEGBA) and the other in charge of generating and distributing gas for household and industrial consumption. Other contributions of the Argentine team were a study of the emergence and development of engineering and consulting firms in the chemical process industries, a detailed analysis of two research centres within the national industrial technology institute (INTI), and two short papers on capital accumulation and on the crisis of capitalism.

The Argentine team followed the methods guidelines; however, they produced a series of thematic reports on issues of actual and potential interest to policymakers in the country, coinciding with the themes selected for study in STPI.

BRAZIL: The Brazilian team was hosted at the research group of the Financiadora de Estudos e Projetos (FINEP), the state agency in charge of financing studies for investment projects and also the executive arm of the national fund for scientific and technological development. The first coordinator was the director of the research group, Fabio Erber. When he took a leave of absence from FINEP in September 1974, he was replaced by José Tavares, the new head of the research group. The group at FINEP had been carrying out research on science and technology policy for some time, and the STPI assignment was one of its tasks for 1973-76. Practically all of the work was done by members of the FINEP research group, although two or three reports were contracted to professionals outside FINEP.

From the beginning, the Brazilians decided to concentrate on the role of state enterprises in technology policy. They chose branches of industry that were dominated by state enterprises (oil and petrochemicals, steel, and electricity), conducting detailed interviews, analyzing existing data, and testing hypotheses systematically to cover issues such as the selection of equipment and processes, the purchase of engineering services, the performance of research and development, and the planning activities at these state enterprises.

In addition to the new material generated by the Brazilian team during STPI, several reports based on past research carried out by FINEP were made available to the STPI network. These included background reports on the organization and structure of the Brazilian science and technology system, a study on the machine tool industry, a report on the demand for services of 12 research institutes, and a background report on industrial policies in Brazil during the last 2 decades.

In parallel with the work for STPI, the FINEP team was also engaged in a research project on the diffusion of technical innovations in three industrial branches (pulp and paper, cement, and textiles) and they agreed to put their results at the disposal of the STPI network as an additional contribution.

The Brazilian team used the guidelines only as a general reference, given that most of their work went along different lines from those originally envisaged for the project. Nevertheless, the richness and variety of their material effectively upgraded the comparative reports.

COLOMBIA: No Colombian participant was present at the initial organizing meeting, and the Colombian application to join the STPI network was received later and formally accepted at the Rio meeting of the coordinating committee. The team was hosted by the Colombian Council for Science and Technology, COLCIENCIAS, and was headed by a sociologist, Fernando Chaparro. In spite of joining the STPI network late, the Colombian team caught up with the pace of work and finished all its work by the deadline.

COLCIENCIAS organized a special team with five members who devoted practically all their time to research in STPI. Several other consultants were also asked to prepare reports on issues of specific interest such as selected policy instruments. For example, a study was commissioned on the impact of tariff mechanisms; a report was prepared on the influence of price controls; and a preliminary analysis of the possible use of the state's purchasing power as an instrument of technology policy was also prepared. The branches chosen for study were all linked to agriculture: fertilizers and pesticides, agricultural machinery, and food processing, taking into consideration the interests of Colombian policymakers as perceived by the team. In these branch studies, the methods guidelines were closely followed.

Other reports prepared by the Colombian team include a study of science and technology planning, an analysis of implicit industrial technology policies, a conceptual framework for the study of consulting and engineering organizations, a series of reports on industrial branches based on discussions with panels of experts, a study of science and technology policies in the agricultural sector (to complement the analysis done for industry), and two essays on the process of industrialization in Colombia and its technological implications.

Five groups of policy instruments were studied in detail, and their impact on each branch was examined through interviews at various enterprises. All of the findings were integrated into the final report of the Colombian team.

EGYPT: Although an Egyptian representative participated in the initial deliberations leading to the STPI project, it was not possible to organize the team to carry out research and prepare inputs for the international comparison. There were several administrative difficulties and staffing problems that prevented the organization of a working team. The host institution was the Academy of Scientific Research and Technology and the first coordinator was Adel Sabet, who was replaced by Gamal A. Samie in July 1975. The Egyptian team presented papers that were personal contributions based on past experience rather than the result of research carried out by a team; and research was not begun at the academy until the second half of 1976.

INDIA: The host organization in India was the National Committee on Science and Technology, and the first coordinator was Anil Malhotra, who was replaced in June 1975 by S.K. Subramanian. Mr Subramanian resigned in March 1976, and no one replaced him. No funds were requested to set up a country team in India, and the Indians provided background material that had already been collected as background for a new science and technology plan.

Three background documents were distributed along with the final S & T plan to all the teams in STPI. In addition, a report on foreign collaboration, a note on science and technology planning in India, a survey of engineering consultancy services, a report on the development of the electronics industry, and two papers on small-scale industries and technology transfer were distributed by the Indian coordinator. No empirical research was done following the methods guidelines, and the Indian contribution to the comparative reports reflects this.

SOUTH KOREA: The South Korean team was one of the first to be organized and was estalished at the Korean Advanced Institute of Science, KAIS, as part of the activities of its science, technology, and society program. KunMo Chung was named country coordinator and the team consisted of five other members. All but one of them had other academic duties and could allocate only a portion of their time to STPI research. Then, Graham Jones was hired to advise in the preparation of the report for phase 1.

The South Korean team advanced rapidly and completed its work in time for the Sussex workshop, following the methods guidelines and introducing modifications only where necessary. Two reports were produced corresponding to the requirements for phases 1 and 2 of the project.

The branches chosen for study were electronics, petrochemicals, and powder metallurgy, and a report was prepared for each one. In addition, the team prepared documents on engineering services and industrialization in South Korea, on the Korean Institute of Science and Technology, on transfer of technology in the electronics industry, on the interface between the science and technology plan and the economic development plan, and on state enterprises in technical development.

Although most of the work was done by the team located at KAIS, consultants were asked to deal with specifics. The team predominantly represented engineering and physical sciences, but an economist who was a senior government official, helped to relate the results to South Korean policymakers and to balance the other team members' biases.

MEXICO: The Mexican team was among the first to start working in STPI and was located at El Colegio de Mexico, an academic and social research and graduate training organization. Alejandro Nadal was country coordinator and there were four other members of the team who worked full time on STPI. The Mexican team initially followed the guidelines rather closely and was one of the first in suggesting modifications and changes as a result of contrasting concepts with preliminary research findings. In particular, the team found it difficult to interpret the results of interviews in enterprises using the schema proposed to study technological behaviour. The branches chosen for detailed study were capital goods, food processing, and petrochemicals.

A background report on the structure and evolution of the Mexican scientific and technological system was prepared, together with a description of the industrialization process and of agricultural development. Documents on particular subjects included a report on engineering firms, a study of the technology policy of PEMEX (the state oil monopoly), and progress reports dealing with hypotheses on the impact of policy instruments on technical behaviour at the enterprise level, a description of policy instruments in Mexico, etc.

Most of the findings of the Mexican team were integrated into the main final report, part of which was delivered at the coordinating committee in New Delhi (January 1976) and the rest at the Sussex workshop (June 1976). The work of the Mexican team covered practically all the research topics considered in STPI, and its contribution to the comparative report reflects this. The Mexican report was published in Spanish in 1977 and was awarded second prize in a contest for the best works in economics.

For various reasons, the Mexican team chose to limit its direct interaction with policymakers and followed its own research program. Results were made available to policymakers in the form of draft reports, and through the participation of the coordinator in one of the committees established to prepare the Mexican plan for science and technology.

PERU: The Peruvian team was established within the research group of the National Planning Institute. A series of administrative difficulties affected the progress of the team, including a change of technical director, when Fernando Gonzales Vigil was replaced by Roberto Wangeman in February 1975. Approximately two-thirds of the research was completed in time for the Sussex workshop.

From the beginning, the team decided to adopt a sectorial approach to the research. Efforts were focused on the study of industrial branches connected with the extraction and processing of minerals and with the provision of machinery for the mining industry. The steel industry was also studied, with emphasis on the state enterprise in charge of the largest steelworks. This meant that the guidelines were used primarily in sectorial studies and in the analysis of policy instruments.

Background reports on the situation of the scientific and technological system and on the evolution of Peruvian industry were prepared following the general framework put forward in the guidelines. In addition to these and the sectorial reports, the team prepared other documents, dealing with issues such as explicit and implicit science and technology policies, consulting and engineering capabilities, the possible use of state enterprises as instruments of technology policy, and the government administrative machinery for science and technology policy.

The Peruvian team was located within an official government organization, but its direct impact on policymaking is difficult to assess because it took the form of daily contact with government officials. On the basis of the sectorial reports on mining, a committee has been set up to review the findings of the STPI team.

VENEZUELA: The Venezuelan team was hosted by the national council of science and technology (CONICIT) and was among the first to start working. The team was initially dominated by sociologists, although economists increased their participation at later stages. The first coordinator, Dulce de Uzcategui, was replaced by Luis Matos, who was soon followed by Ignacio Avalos. Three other members worked full time, and the team was biased toward sociology and economics.

They progressed through two stages punctuated by a change in government. In the first stage, most of the background reports corresponding to phases 1 and 2 of the STPI methods were prepared, covering the science and technology, the political, the educational, and the economic systems. These reports were made obsolete by the change in government. In the second stage, the team tried to adjust to the new situation, repeating some of the earlier studies and continuing the research. However, the organization of a national congress on science and technology, which mobilized all the staff working at CONICIT, affected the team's progress.

The branches chosen for study were capital goods, electronics, and petrochemicals. In addition, reports were written on specific issues such as the governement organizational structure for science and technology policy, instruments for industrial science and technology policy, economic and financial policy instruments and their impact on technology, the purchase of capital goods in two industrial branches, and the relations between the financial system and technology policy. The Venezuelan team concluded its research shortly after the Sussex workshop.

The fact that the Venezuelan team was located in a government agency that took a very active role in science and technology policy after the change in government created both opportunities and problems. As a result of the new tasks undertaken by CONICIT, the pace and continuity of the STPI work was frequently altered. On the other hand, there was more possibility for actively contributing to policymaking. The Venezuelan contribution to the comparative reports reflects this situation.

YUGOSLAVIA (MACEDONIA): The Macedonian team was organized at the faculty of economics of the University of Skopje. A senior faculty member, Nikola Kljusev, was appointed coordinator. The team was composed of a very large number of faculty members and researchers who devoted part of their time to STPI. The tasks were subdivided and individual reports requested from various members of the team, although at a later stage two team members were asked to work full time on STPI.

The Macedonian team did not follow the guidelines, except in the preparation of a background report for phase 1. Individual reports were submitted on issues of interest to the STPI network, covering topics such as the problems of research and development in industrial enterprises, aspects of science and technology policy in Yugoslavia, the metallurgical industry in Macedonia, and the growth of engineering firms in Yugoslavia.

The Macedonian team's specificity is reflected in their relatively limited contribution to the comparative reports. At any rate, given the high degree of participation of professionals at all levels in policymaking in the Yugoslav self-managed economy, it is rather difficult to assess their contribution toward policymaking in conventional terms.

THE FIELD COORDINATOR'S OFFICE: In August 1973, at the first meeting of the coordinating committee, Francisco Sagasti was appointed field coordinator of the project and his office was established shortly thereafter and began operating in a limited way. Staffing was completed in April 1974 with the addition of two members.

The field coordinator's office was independent from the teams and was not engaged directly in empirical research. It offered organizational and technical support and contracted consultants to prepare reports on topics defined by the coordinating committee.

The field coordinator, first, drew up methods guidelines for phases 1 and 2 of the project. Background reports on technology policy in China, on technological dependence/self-reliance, on science and technology planning, on technology policies in Japan, and on technology transfer were also prepared, either by staff members of the field coordinator's office or by consultants. The guidelines for phases 3 and 4 of the project were prepared jointly by the field coordinator and a consultant. The office also organized the Sussex workshop and drafted the comparative reports. The field coordinator was also active in the board of the Peruvian Industrial Technology Institute (ITINTEC).

With the exception of the teams that were engaged in science and technology policy research as part of the activities of their institutions (the Brazilian and South Korean teams, for example), the teams were dismantled after the STPI project was completed. The field coordinator's office was closed in December 1976, and the comparative reports were prepared during 1977-1978, although some teams had not finished their work by April 1978. Even though most teams had concluded their STPI activities by the end of 1977, this does not mean that the team members left the field of S & T policy research and that their effort in STPI was not followed up. What was dismantled, as planned from the beginning, was the formal structure of the STPI project. The network of personal contacts remains in operation and most of the former team members are active in the field of science and technology policy, carrying the experience accumulated in STPI to their new positions.

Key to STPI Publications

STPI

Primary

(1) The STPI Project
(2) Methodological Guidelines
(3) Main Comparative Report
(4) Planning
(5) Chinese Technology Policy/ Industrialization

Modules

(6) S&T: Differing Schools of Thought
(7) Evolution of Industry
(8) Evolution of S&T
(9) S&T - Present Status
(10) Policy & Generation of Technology
(11) Policy for Imports
(12) Policy for Technology Demand
(13) Policy to Promote Industrial S&T
(14) Policy for Industrial S&T Support
(15) Industrial Technical Changes
(16) Industrial Technology Behaviour
(17) Technical Change Studies

Selections

(18) S&T Policy & Development
(19) Engineering Consulting & Design in LDCs
(20) Technology Transfer in LDCs
(21) State Enterprises & Technological Development

Background Papers

(22) El INTI en la Industria Argentina
(23) El Sector Maquinas Herramientas en la Argentina
(24) Los Instrumentos de Politica Cientifica y Tecnologica en Argentina
(25) Brazilian Machine-Tool Industry
(26) Los Bancos y Comercializacion de Tecnologia
(27) La Industria Petroquimica
(28) La Variable Tecnologica y las Variables Horizontales
(29) Indian Electronics Industry

Country Papers

(30) Mexico
(31) Korea
(32) Peru
(33) Colombia

A GUIDE TO THE SCIENCE AND TECHNOLOGY POLICY INSTRUMENTS (STPI) PUBLICATIONS

A. Primary Publications

(1) The Science and Technology Policy Instruments (STPI) Project (IDRC-050e) (out of print)

(2) Science and Technology Policy Implementation in Less-Developed Countries: Methodological Guidelines for the STPI Project (IDRC-067e) (out of print)

(3) Science and Technology for Development: Main Comparative Report of the STPI Project (IDRC-109e). (Also available in French (IDRC-109f) and Spanish (IDRC-109s).)

(4) Science and Technology for Development: Planning in STPI Countries (IDRC-133e)

(5) Science and Technology for Development: Technology Policy and Industrialization in the People's Republic of China (IDRC-130e)

B. Modules

These constitute the third part of (3) above and provide supporting material for the findings described and the assertions made in (3).

(6) STPI Module 1: A Review of Schools of Thought on Science, Technology, Development, and Technical Change (IDRC-TS18e)

(7) STPI Module 2: The Evolution of Industry in STPI Countries (IDRC-TS19e)

(8) STPI Module 3: The Evolution of Science and Technology in STPI Countries (IDRC-TS20e)

(9) STPI Module 4: The Present Situation of Science and Technology in the STPI Countries (IDRC-TS22e)

(10) STPI Module 5: Policy Instruments to Build up an Infrastructure for the Generation of Technology (IDRC-TS26e)

(11) STPI Module 6: Policy Instruments for the Regulation of Technology Imports (IDRC-TS33e)

(12) STPI Module 7: Policy Instruments to Define the Pattern of Demand for Technology (IDRC-TS27e)

(13) STPI Module 8: Policy Instruments to Promote the Performance of S and T Activities in Industrial Enterprises (IDRC-TS28e)

(14) STPI Module 9: Policy Instruments for the Support of Industrial Science and Technology Activities (IDRC-TS29e)

(15) STPI Module 10: Technical Changes in Industrial Branches (IDRC-TS31e)

(16) STPI Module 11: Technology Behaviour of Industrial Enterprises (IDRC-TS32e)

(17) STPI Module 12: Case Studies on Technical Change (IDRC-TS34e)

C. Selections

These are a selection of the numerous reports prepared for the STPI Project chosen as a representative sample of the various topics covered by the STPI Project in the course of the main research effort on policy design and implementation.

Science and Technology for Development: A Selection of Background Papers for the Main Comparative Report.

(18) Part A: Science and Technology Policy and Development (IDRC-MR21)

(19) Part B: Consulting and Design Engineering Capabilities in Developing Countries (IDRC-MR22)

(20) Part C: Technology Transfer in Developing Countries (IDRC-MR23)

(21) Part D: State Enterprises and Technological Development (IDRC-MR24)

D. Background Papers

(22) El INTI y el Desarrollo Tecnologico en la Industria Argentina (In press)

(23) El Sector Maquinas Herramientas en la Argentina (In press)

(24) Los Instrumentos de Politica Cientifica y Tecnologica en Argentina (In press)

(25) The Brazilian Machine-Tool Industry: Patterns of Technological Transfer and the Role of the Government (In press)

(26) Rol de los Bancos en la Comercializacion de Tecnologia (In press)

(27) Comportamiento Tecnologico de las Empresas Mixtas en la Industria Petroquimica (In press)

(28) Interrelacion Entre la Variable Tecnologica y las Variables Horizontales: Comercio Exterior, Financiamiento e Inversion (In press)

(29) A Planned Approach for the Growth of the Electronics Industry — A Case Study for India (In press)

E. Country Reports

(30) Instruments of Science and Technology Policy in Mexico (In press)

(31) Technology and Industrial Development in Korea (In press)

(32) Los Instrumentos de Politica Cientifica y Tecnologica en el Peru: Sintesis Final (In press)

(33) STPI Country Report for Colombia (In press)