Science and Technology Indicators for Development

edited by
Hiroko Morita-Lou

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lags between the time a paper is published and then cited, while in slow moving fields, the lag is considerably longer. If a researcher using citation data is unaware of these field-to-field differences, he or she may misinterpret his/her finding.

5. **The institutional address problem.** Different abstracts and indexes follow different policies in reporting the institutional addresses of authors, ranging from no institutional information to detailed information.

6. **The Abstract/Index Coverage Problem.** Some abstracting and indexing services are very consistent in their journal and article coverage policies. The *SCI,* for example, covers all papers appearing in a well-defined set of journals. Other abstracting/indexing services may be very haphazard in what they cover, including only those pieces that happen to come to their attention in some random fashion.

7 The Effects of Science and Technology on Development: Observations on Strategies for Research

Archibald O. Haller

GENERAL CONSIDERATIONS

The Promise

It is increasingly apparent that advances in S&T knowledge continue to enhance the ability of the richer nations to manipulate nature in ways that are advantageous to their peoples. Naturally, there are adverse consequences, which concerns about toxic chemical and radiological pollution and the increasingly destructive power of modern weaponry make clear. And it seems evident that advanced science and technology is required, though it is not sufficient, to bring the unwanted effects of science and technology under control. This paper presents a number of considerations and experiences of possible use to those who are interested in the establishment of scientific and technological institutions to promote development in developing countries.

Without trying to specify a fully defensible meaning for the terms, it seems clear that scientific and technological knowledge differ from each other. The former is the more complex—knowledge accruing from observation and analysis in the attempt to provide progressively more comprehensive yet ever simpler sets of concepts concerning entities and their relationships, including the variations that such entities may undergo and the proximal causes and consequences of such variations. Technological advances consist of new routines by which to achieve proximally practical ends. The latter—technological knowledge—may be seen as knowledge of proven procedures by which to achieve predetermined goals. Scientific advances consist of new or improved theoretical explanations of phenomena. From time immemorial new technological improvements have evolved from older ones, with or without science.

Science, however, emerged during the past few centuries, and to some extent it too has a life of its own. But these comments do not imply that scientific and technological knowledge are always independent of each other. Modern science depends upon technology to contrive observational and analytical procedures and to disseminate research results. And much contemporary technological knowledge is based upon science. Indeed, one might define the current term "high technology" as sets of practical routines and their material counterparts based largely on recently developed scientific theory. By this definition the electric motors of a century ago were the "high technology" of their day just as computers are today. In the richer nations, S&T knowledge and institutions are thoroughly integrated with each other and they in turn with the rest of the socio-economic structure. In such countries it is obvious that S&T institutions are supported by the national wealth and that they also contributed to it.

With experiences of such nations serving as examples, it is not surprising that many believe the establishment of indigenous S&T institutions could release the people of poorer nations from the constraints of time, distance, natural disasters, poverty, illness and untimely death. Thus the promise of a better life is surely a major incentive behind current efforts to improve the S&T capacity of such nations.

There may be another incentive—a fear of possible deleterious consequences among poorer nations when computerization comes to control the manufacturing systems of the advanced nations. Let us explain. Today, a number of poorer nations are attempting to meet the needs and improve the quality of life of their growing populations by using cheap labour to produce manufactured goods for sale in world markets. These countries appear to use basically literate, but scientifically and technologically unsophisticated, labour in their manufacturing systems. The newer computerized technologies—"brain industries"—that are coming on line in the industrialized nations employ fewer production workers per unit product, and they are apparently more highly specialized than manufacturing and could so reduce the per-unit cost of production as to make the former manufacturing systems—"brawn industries"—obsolete. The manufacturing systems of the newly emerging industrial regions, which employ less specialized personnel, might then fall into obsolescence along with the rest of the brawn industries of the world. If reality turns out to match this scenario, the gap between the rich and poor nations would increase even more than it is now, because the poorer nations would be short of the technological capacity to computerize their plants and would lack the personnel to run them. Apropos of this, preliminary calculations show—not surprisingly—that average secondary and tertiary school enrollment rates of the established manufacturing nations with market economies far exceed those of newly industrializing countries (Brazil, Republic of Korea, Argentina, Singapore, Hong Kong, and Mexico). But it is worth noting that while the value added through manufacturing per industrial worker (VAM/W, an estimate of productivity per worker) increases with tertiary enrollments in the established manufacturing nations, precisely the opposite appears to occur among the newly industrializing nations. There, the higher the tertiary enrollments, the lower the worker's productivity (VAM/W). (Original calculations, from data in World Bank, 1984: 218–219, 231–232, 258–259, and 266–267.) Together, these data suggest that the newly industrializing nations are indeed placing their bets on a relatively uneducated labour force, and that in today's markets the less emphasis they give to higher education the more successful they are. But if in the next decades the brain industries drive the brawn industries out of the market, today's successes among the poor nations will be tomorrow's failures, joining those that never entered the race.

Therein lies the second stimulus for encouraging the improvement of the S&T capacity of poorer nations—to better enable them to be among the producers of a wide variety of manufactured items, consumer goods, and the various productive forces that manufacturing can generate. This may not apply only to manufacturing. Some poorer countries anticipate similar benefits from technologically sophisticated agriculture.

The Practicalities

But are indigenous capacities for science and technology really necessary? Can a poor nation reap the benefits of science and modern technology without going to the expense of building strong science or technology capacities? And even if they were to be built, would they really help to develop the country? These questions are not easy to answer. Some seem to believe that it is the technology that is needed, not the science. Some may think that effective and mutually supportive scientific and technological capacities are necessary but take the expected benefits for granted. Still others may doubt the necessity of either or may want to see evidence of their presumed benefits.

A number of pitfalls or problems are implied by such questions. We shall discuss one set of them at length—the problem of determining whether and to what extent a scientific or technological capacity affects development.

But there are observations that should be noted before entering that discussion. The first concerns real-world differences between science and technology. The others concern the interdependence of S&T, not only with each other but also with the educational system.

First, in the richer nations science not only yields more scientific knowledge, it also breeds technology. And advances in technology often feed into research that enhances scientific knowledge. But technological knowledge is secret while scientific knowledge never is. Technological knowledge is treated as secret or as protected when organizations (occasionally individuals) have a great deal to gain by monopolizing it or a great deal to lose by failing to do so. Private organizations guard their new technologies closely, at least until they have obtained patent rights to protect their monopolies over them. Governments sometimes do so too, and in addition try to keep new military technologies secret as long as possible. Scientific knowledge with obvious consequences for military use also is often threatened with classification by governments. (A recent instance in which a mathematician developed a system capable of breaking the most advanced codes is a case in point.) Beyond this, private firms or even their governments may try to hedge unpatented technologies in secrecy, especially if large profits are expected. This might not be hard to do when such technologies flow from unique and complex applications of scientific knowledge that only a few people understand. Nonetheless it would appear that practically all scientific knowledge and much technological knowledge is presented openly. A considerable amount of agricultural technology is public and fairly easy to employ, although some, of course, will be patented. In the years to come, for example, many of the technologies that genetic engineering is expected to yield will no doubt be protected.

The point is that societies treat the two types of knowledge differently in ways that will be important to the poorer nations. New scientific knowledge often has no obvious applications. Its payoff for development is at best indirect and quite a few scientific advances may not yield any development advantages for the nation. But for those who know how to decifer it, scientific knowledge is usually easy to obtain. In contrast, new technological knowledge is much more likely to yield development benefits—if it can be had. Unfortunately, many manufacturing technologies and even some agricultural technologies are deliberately placed out of reach of all but those who own special rights to them. So countries that want to reap the benefits of many of the new technologies may need to develop the capacity to produce them.

Second, if science is open but technology is closed, some may conclude that scientist-guided institutions for generating new technology are worth supporting but that scientific institutions are not. That is, some of the most promising, potentially competitive new technologies will be based upon scientific knowledge. So it might be thought that a poorer nation should put its scientists in technological institutes so that they can keep track of the emerging scientific literature and translate it into technological

innovations. Such a strategy would no doubt be accompanied by another, holding that few scientists and many technicians should be employed in such institutes. The strategy probably will not work without substantial modification. First, most scientists are narrowly specialized, but scientific knowledge covers an immense variety of domains. Most scientific publications will be unintelligible and, for all practical purposes, inaccessible to most scientists: The *Science Citation Index*, for example, covers about 2,500 journals each year, of which 500 or so are considered as "high impact" (Garfield, 1983a). Third, most of the scientific literature such a scientist would read would be irrelevant to the technological aims of his institute. Fourth, divorced from the actual practice of theoretical research, the once well-prepared scientist would soon become obsolete. At best he might turn into just another technician—possibly capable of a bit more penetrating thought than his colleagues, but with a grasp of the advancing state-of-the-art theory that is no better than theirs. Worse, he will not only fail to keep up; he will lose much of what he once knew because he was unable to use it. As their scientific leadership becomes obsolete such institutes will surely lose their creativity.

Yet the basic idea of this strategy may yet be sound. If scientific knowledge, which is relatively open, can be drawn upon to elicit locally relevant new technologies, some of the obstacles to technology transfer might be by-passed. This would require arrangements that facilitate identification and mastery of the relevant fractions of scientific knowledge. A special need is for local scientists to keep up-to-date through significant participation in creative scientific research with equally serious participation in local technology identification and development research. Perhaps scientists of specialized local technological institutes could have ready access to international electronics networks of scientific journal literature and could be actively involved in the research of a major international scientific center while maintaining appropriate involvement in the work of the local technology center.

A third major point is that even if full-fledged, well-functioning capacities for both science and technology were to be established and coupled to effective technology delivery systems, they might not be sufficient in themselves to make much of an impact on the development of the society. This point may be particularly relevant if the nation decides to produce its own high technology and to employ it in mass production. The problem is the shortage of qualified workers. Granted, some high technologies yield manufacturing or agricultural systems that use a certain amount of brawn labour. But they will surely require an increase in the number of personnel who are capable of handling, operating, and repairing the complex equipment that the new technologies yield. This implies that the newly emerging forms of agriculture and industry may require better educated, more sophisticated personnel than formerly, if the benefits of the new establishments of science and technology are to have their greatest effects on the development of the nation. If the nation's labour force lacks the sophistication to take advantage of the production potentials offered by its S&T establishments, many of the expected benefits will never materialize.

As is becoming more and more apparent, capable and diversified establishments for generating scientific and technological knowledge will be costly and may take a long time to bring to the point at which they can serve the development needs of a nation. And as they are built, it may also be necessary to prepare production systems and personnel who are capable of operating them. A fourth point follows from this. Because of the costs, it may be necessary for many countries either to combine their efforts, to specialize them narrowly, or both. A nation's ability to create such establishments will be a function of the size of its total economy. Nations that are rich already have such organizations, many of them, especially those devoted to science, as parts of universities. Populous poor nations, such as Mexico, Brazil, China, India and Indonesia may be able to do so because of the total resources their large populations can generate. By concentrating resources, maybe a few small, poor countries can too. But most of the nations of the world may be too small and too poor to support such units. In some cases, such nations will concentrate their S&T efforts on technical institutes devoted to a few farm crops, ignoring industrial technology. Or a few neighboring countries may join forces to establish technological research units when they are unable to do it alone. It might also be advantageous to encourage substantial involvement of local scientists in research activities of the great scientific centers of the world. It would be expensive to support senior scientists to maintain double careers, one in an indigenous technological institute, the other in a distant center, perhaps even involving payments to host centers to defray the costs of participation. But if it were to raise the rate of useful technological innovation it would be worth the cost.

Summary

In a few words science and technology hold out great promises to the people of the poorer nations of the world, promises abundantly illustrated by the richer nations. Yet the relationships between science and technology and the implications of each for the nation are complex, and the costs of establishing effective S&T institutions will be great. Much is thus to be gained if the development effects of science and technology can be demonstrated. This is not easy. But research on various aspects of the issue are already underway. The next section discusses some of these aspects and provides illustrations of research in which development is the central variable.

THE IMPACT OF SCIENCE AND TECHNOLOGY ON DEVELOPMENT

Those who wish to assess the impact of S&T establishments on development face a formidable task. In brief, to provide secure research evidence it would be necessary to measure the output of the indigenous scientific or technological establishment, the levels of the development variables hypothetically following from these outputs, the levels of other variables which might either function as conveyors of the science and/or technology outputs on the development variables or as measure of variables offering complementary or alternative explanations of the presumed developmental effects of the science and/or technology variables. It would appear that to date the literature on science and technology for third world development has been devoted almost exclusively to questions of the measurement of science and technology, with little or no attention yet being given to measuring either development or the impact of science and technology on development. In this section we first discuss measurement implications of the differences between science and technology. Next we present one example of research designed to measure the average socio-economic development of populations of regions of Brazil. We present a sketch of a research project now underway in Brazil, which is designed to measure the developmental impacts of variations in the use of traditional and research-based agro-technologies as these have been affected by a central technological research and extension establishment. While these illustrations are far from exhaustive, they may provide a glimpse of the less well understood possibilities and complexities of research on the impact of S&T on development.

Science and Technology Compared

Let us turn to the outputs of science and technology. The yields of science are different from those of technology. Strategies for measuring the effects of each will vary accordingly. The development consequences of innovations in science are normally effected, if at all, through their impact on technology. Thus at most the developmental impact of indigenous scientific centers will be indirect. But the outputs of scientific centers will often be easier to measure than those of technological centers. The immediate output of scientific research consists of published new contributions to scientific knowledge. Citations count data would appear to be the most successful indicators of scientific output (Arunachalam and Garg, 1984; Garfield, 1982, 1983a, 1983b; Blickenstaff and Moravcsik, 1982; Rushton and Meltzer, 1981; Turner and Kiesler, 1981; Frame 1980). Yet some—possibly confusing the outputs of technology with those of science—question their validity when used in developing nations (as reported by Blickenstaff and Moravcsik, 1982: footnote on 135). But regardless of the measurement of science output, the indigenous developmental impact of local scientific research might be impossible to measure in the short run. First, much scientific knowledge is accessible regardless of where it is generated. Second, locally generated contributions to science might have but little impact on locally relevant technology. Third, locally relevant technology would ordinarily be copied or adapted from widely available exogenous technology or generated from similarly public exogenous scientific knowledge. And fourth, spin-offs from science normally percolate slowly into practice if at all. However, as we have seen, science may contribute to the efficacy of technological instititutes. So there might be instances in which long-term effects on technological institutes of varying qualities of scientific establishments could be assessed. The next sections of the paper present research examples pertaining directly to development.

Regional Socio-economic Development. This section is devoted to recent work on Brazil's socio-economic macroregions. It illustrates measurement research regarding one aspect of development and thus shows something of the richness of both the possibilities and problems of developing indicators of this aspect of the research task.

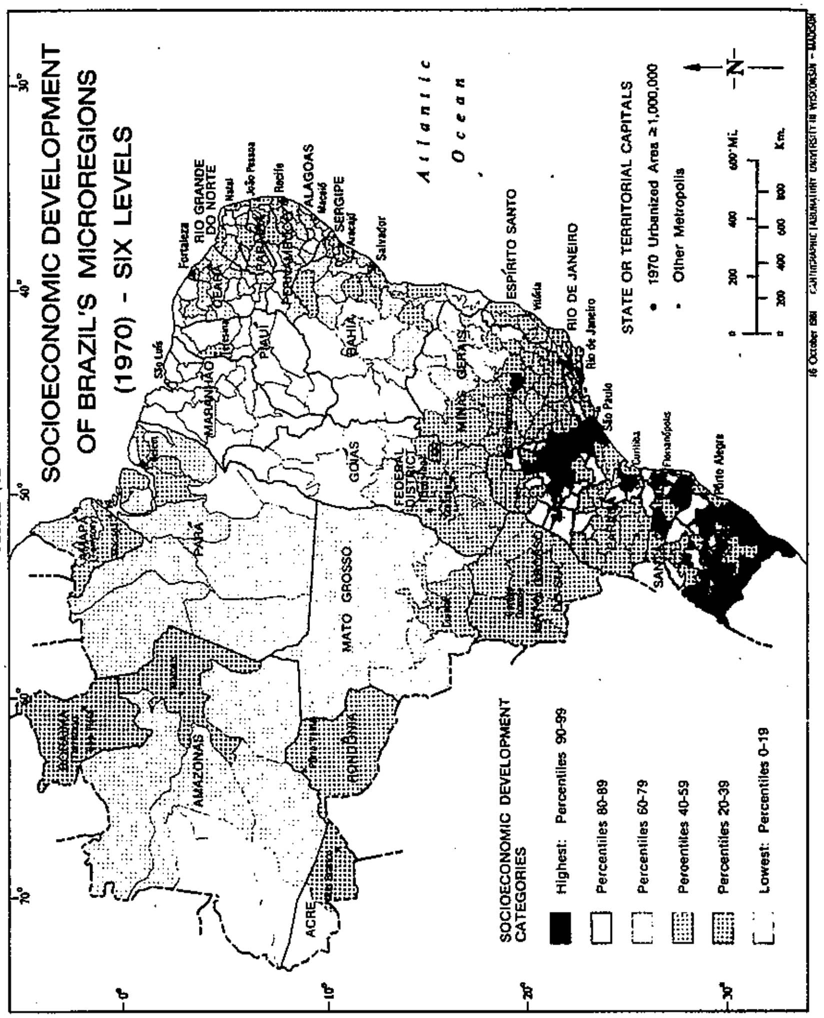
Brazilian scholars and policy makers have long been interested in methods by which to identify Brazil's regions. The nation is so large and so diversified that it is obvious that its natural and socio-economic regions must be taken into account. This has led to many attempts to regionalize the nation. Of course, different criteria yield different arrangements of units such as states, etc., into macroregions. These have been summarized elsewhere (Henshall and Momsen, 1974), and we do not need to go into them. Recognizing in a general way the enormous differences in development levels of the populations of different areas of Brazil, such as Sao Paulo and Rio de Janeiro on the one hand and the Northeast on the other, scholars have recently begun to try to learn how to provide precise specifications of the nation's socio-economic development macroregions.

One such analysis was performed by a University of Wisconsin research team (Haller, 1982, 1983). The analysis utilizes public statistical data aggregated to the level of the macroregion. For some years Brazil has employed homogeneous areal units (municipios and contiguous sets of municipios called "microregions," among others) as bases for regional analysis (IBGE, 1970). On the continent, 360 microregions are so

identified. Large numbers of variables have been aggregated to this level and are available for various research purposes. For the present analysis, a few variables were selected as possible indicators of the socio-economic development of the population of the microregions. There are two rational ways to make such a selection. The preferable one is to use variables that are dictated logically by a powerful theory. When no such theory exists, a reasonable alternative is to draw upon the accumulated research experience to suggest variables. This was done in the case we are discussing. For it, two old and powerful lines of research seemed appropriate. One focusses on the economic development differences among nations, the other on household or family socio-economic status. When applied to Brazil's microregional data, the two lines suggest a short, overlapping list of items (each reduced to a per capita rate so as to develop an indictor of the average condition of the data) which were the number of factory employees per worker, the agricultural participation rate, the value of commercial sales per capita, the literacy rate, and access per capita to radios, refrigerators, television sets, and automobiles. The experience of the researchers makes it clear that these would be positively intercorrelated. But their factor structure was not entirely predictable. Two possibilities seemed most likely: 1) that two factors might describe the correlation matrix—economic status, saturating the first three, and household socio-economic status (Sewell, 1940) saturating the last four, with literacy perhaps tied to both; and 2) that one factor might saturate the whole matrix. The first outcome would have argued for the existence of two multi-item variables describing the condition of the population's microregional economic development and microregional household socio-economic development. The second possible outcome argues for just one such variable—microregional socio-economic development. Factor analysis showed the one-factor solution to be correct. This being the case, it was possible to construct a factor-weighted index score indicating the relative socio-economic development (SED) level of each microregion.

The unique aspects of this analysis are two: 1) the systematic non-haphazard selection of socio-economic indicator variables and 2) the use of small units, the microregions rather than the customary states and territories, as the building blocks for the macroregions. When the SED scores of the microregions are laid out on the map of Brazil they show facts that are most interesting, some new, some already well known. The details are presented in the two essays just cited and are reflected in Figure 7.1 (from Haller, 1982:458). As Brazilians have known for years the population of the south is better than that of the north. But conclusions that do not seem to appear in the previous literature include the following: the most marked single SED macroregion is an area of

FIGURE 7.1



uniformly very low SED running south from Sao Luis to near Brasilia and extending from western Pernambuco to eastern Para, encompassing the people of about 20% of Brazil's land surface. As indicated in Figure 7.2, we label it the "Underdeveloped New Northeast." In a way, the most pronounced feature is not entirely old information: the SED homogeneity of the southern areas from the south of Minas Gerais through Rio Grande do Sul. In terms of the SED of the people of its microregions the whole South is perhaps more uniformly high than many have thought. A third, and completely unanticipated, feature is the South's Developing Periphery, a set of microregions of middle-level SED scores that arc across the north rim of the South, from Espirito Santo through Minas Gerais, across southern Goias, through Mato Grosso do Sul and perhaps out to eastern Acre. We labled the whole area the "South's Developing Periphery," and its two sub-areas as the Rim (the area arcing across the top of the South) and the Ray (the area running out along the national border to Acre). The Northeast is a fourth feature. It is composed of a set of continuous near-coastal microregions from the south of Bahia and the northeast of Minas Gerais north through most of Ceara. Its SED characteristic (unlike the former macroregions) lies not in its homegeneity but in its (generally low-level) SED heterogeneity. We label it the "Unevenly Developed Old Northeast." The remaining macroregion is the sparsely populated "Undeveloped Amazonian Frontier." One other observation is useful: while most of the microregions containing the great cities and industrial might of the nation have high SED scores, many of the highest scoring microregions are in the rich agricultural regions of the South, especially in Rio Grande do Sul and Sao Paulo. (Figures 7.3–7.5 illustrate combinations of SED data with those of population density.)

This illustrates an approach to measuring socio-economic development within a country. Other conceptions of development, such as populational health characteristics are possible and might lead to somewhat different regionalizations. In any case, this type of measurement can be performed on countries having the necessary data. Combined with other appropriate information, such data might be used as an element in tests of hypotheses concerning the covariations of science and/or technology and development. Indeed, a Brazilian team has prepared maps of the distribution of modern versus traditional agro-technology that yield delineations of agricultural regions resembling the ones we have just noted (Mesquita, Guzmao and Silva, 1977).

Those interested in assessing the effects of indigenous contributions to science and technology may also note some of the complexities revealed by this illustration. Covariations of the regional distribution of scientific or technological effort or output with development might

FIGURE 7.2

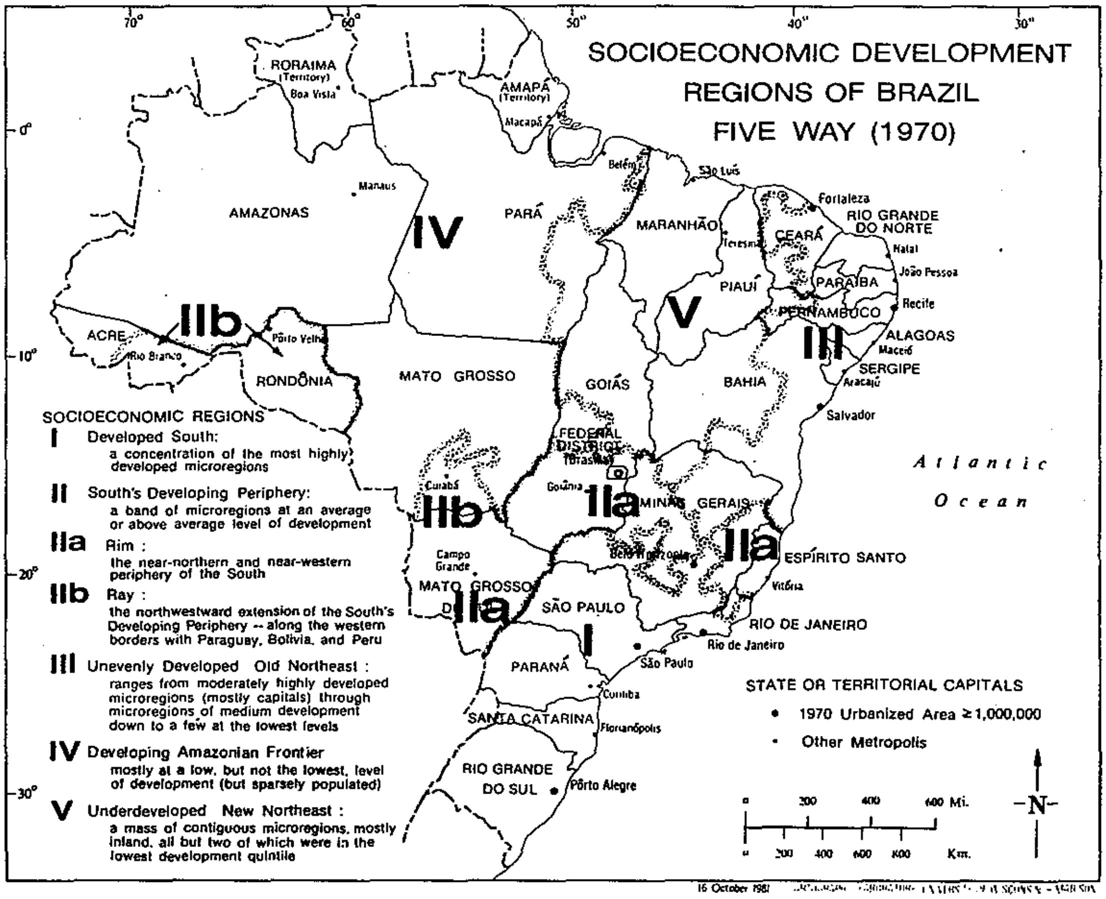


FIGURE 7.3

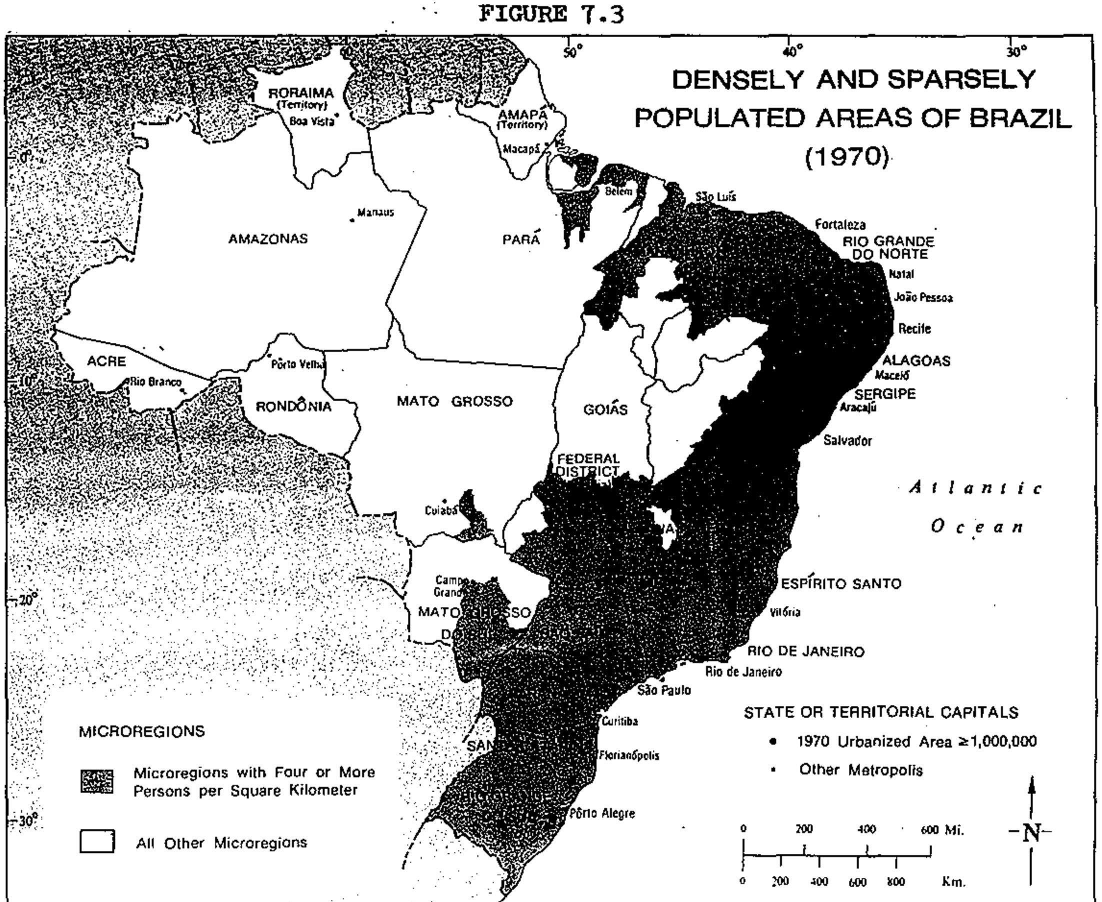


FIGURE 7.4

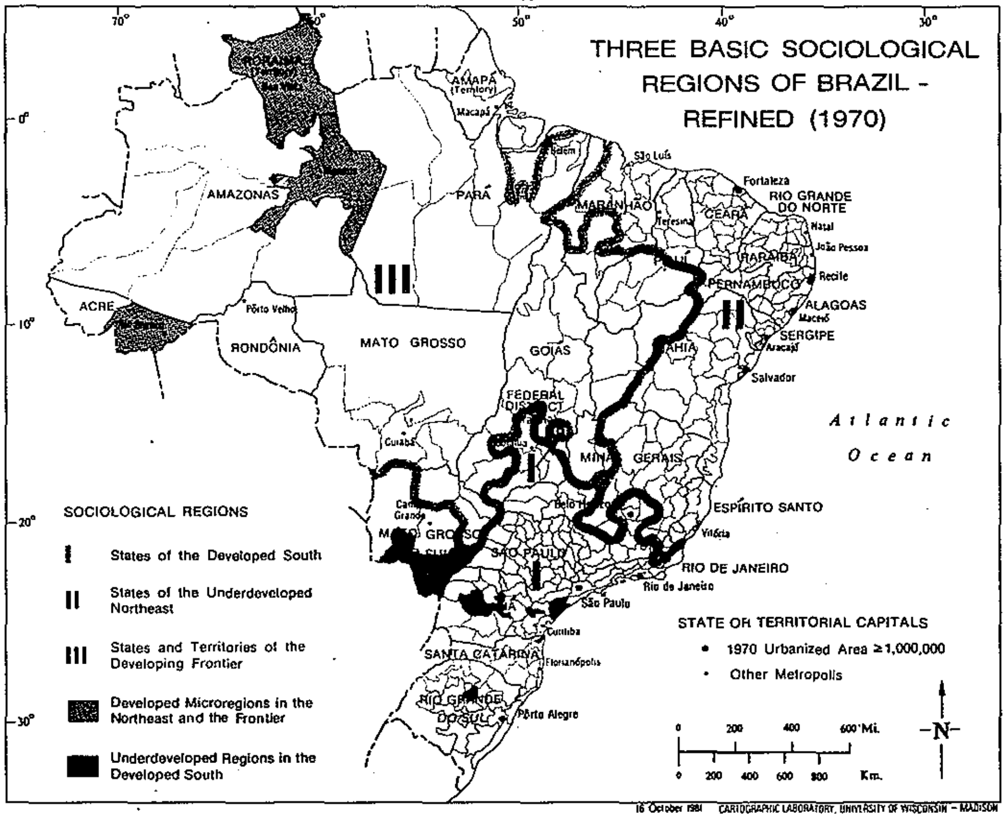
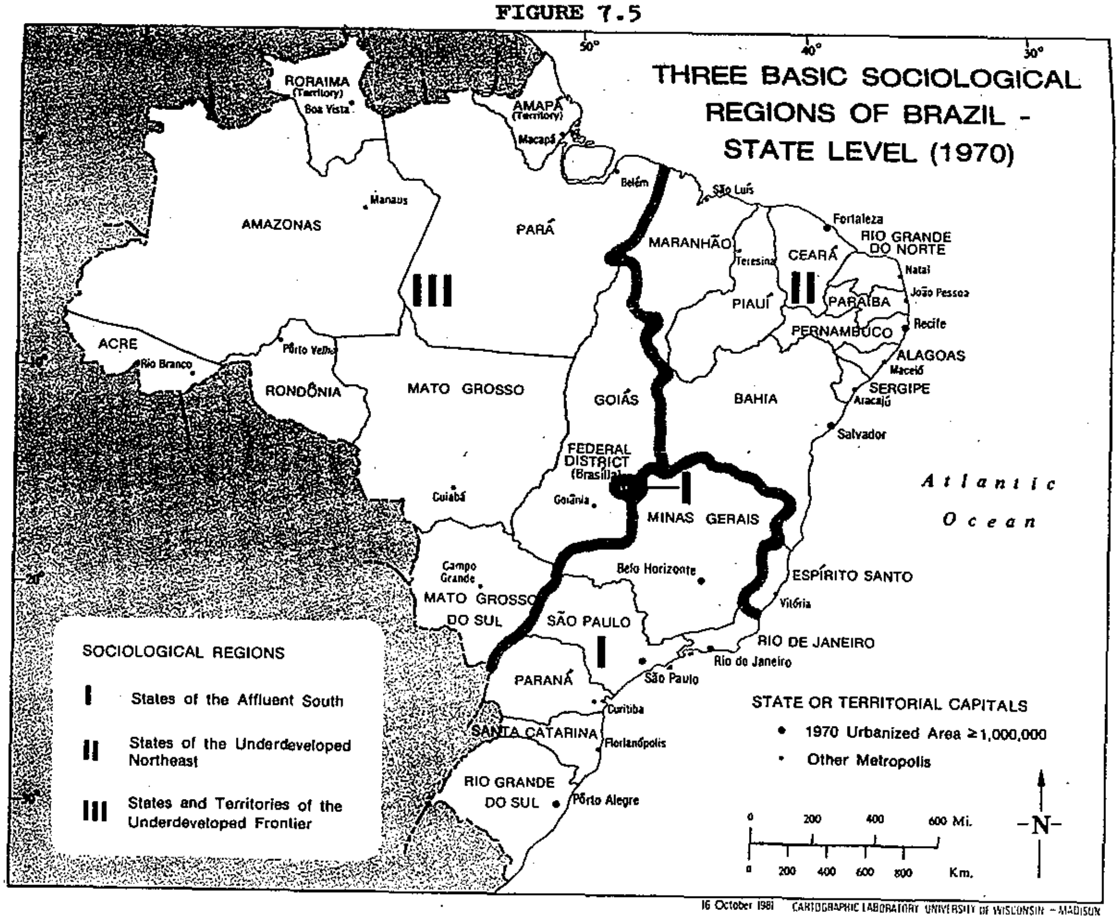


FIGURE 7.5



be enlightening. But it might be difficult to demonstrate cause-and-effect relationships. Measures of covariations that specifically incorporate changes in the levels of both classes of variables, allowing for lagged covariations and taking the effects of other covariants into account might help to overcome the problem of identifying causal patterns. In turn this is a reminder of the need to obtain time-series data on the variables to be incorporated into such models.

The Impact of a Local Research Center. It is not uncommon for developing nations to encourage the establishment of specialized technological research institutes. Often these are parts of universities. Some have limited sets of missions, others multiple missions. Some are arms of academic disciplines and are administered by personnel of such departments. Some are large-scale institutes involved wholly in research. Some are small scale. Some are integral elements of a larger research generation and delivery system, and are thus closely tied to extension operations. The present paragraphs sketch one such technology center, its organizational environment and that of the surrounding area, and provide an overview of ongoing research now underway on its effects on agro-technology and those in turn on the development of the region. The research illustrates another approach to measuring the effects of an establishment generating and distributing the results of technological research. The research is far from complete and the present views are those of an observer rather than a participant.

Cacao is one of Brazil's important export commodities. Practically the whole national crop is grown in the tropical coastal lowland south of Bahia. Cacao production was opened up early in the century. The cacao tree has a life of about 60 years and is most productive during its middle 30 years. By 1960 or so the region's production had declined, and shortly afterward the government decided to establish an imaginative agency to restore production. The agency is called CEPLAC (Comissao Executiva do Plano da Lavoura Cacaueira) and it is the main socio-economic support agency in the 89 municipios comprising the Cacao Region. As an incentive, CEPLAC was assigned a budget proportional to the annual sales of cacao and was allowed the authority needed to use the budget in support of cacao production. CEPLAC set up a research center (CEPEC) and an extension division (DEPEX). Over the years CEPLAC has also provided marketing information, helped set up agricultural cooperatives, provided roads and port facilities, and encouraged the establishment of schools. Its central concern is cacao, of course. But it does not ignore other agricultural products of the area. Indeed in one way or another it touches the lives of all the 2.5 million people who live there. As is normal for extension agencies, DEPEX has local offices through the region. One of the main tasks of the CEPLAC

system combines the forces of CEPEC and DEPEX. CEPEC is intended to keep abreast of and to provide improved agro-technologies for the region. To that end it is led by Ph.D.s in agrobiological sciences, mostly trained in leading universities in the United States. Its leadership is fully aware that technology operates through people, and CEPEC's personnel include Ph.D.s in rural sociology and agricultural economics. It has several divisions for research and research support, including a socio-economic research unit, a fine computation unit centered on high capacity mainframe, and, of course, biological research laboratory facilities. Its staff includes specialists in computer science and in mathematical statistics. It publishes a multilanguage journal of cacao research. As an agricultural extension agency, DEPEX does not seem especially unique. It is intended to function in part as a technology delivery system, as are most extension services. Its personnel are very well trained by most standards. About 50% of DEPEX's staff have university degrees in agronomic engineering, over 300 in all.

It took several years for CEPLAC to become effective. By about 1970 it was apparent that systematic research should be carried out to determine CEPLAC's effects on agrotechnology and on the socio-economic development of the local population. Accordingly, early in the decade, with the sampling advice of IBGE (the national statistical service), the socio-economic research unit conducted a large number of personal interviews with key personnel of each property selected in two different probability samples. One sample used all properties as its units, the other the properties in four pockets of small farmers. The variables and items were selected by fully trained sociologists and economists skilled in social measurement. Data suitable for developing state-of-the-art multiple-item indexes to measure variations in the use of indigenous non-research-based and research-based CEPEC-proven agrotechnologies were included. During 1985, comparable data are to be collected and used to estimate models of the impact of previous technologies on intervening technologies, and agricultural productivity on a series of social and economic development variables.

Inasmuch as CEPEC is the only research agency operating in the area, since it is specifically designed to seek out, develop and evaluate new technologies appropriate to the region's economy, and since its outputs are channeled directly to producers by DEPEX, it is considered to be the only source of new research-based technology available to the region's producers. Thus any changes in the use of research-based technology can be assigned directly to CEPEC and the net changes in both non-research-based and research-based technology will be attributable either to DEPEX (backed by CEPEC) or non-research based innovation. Confirmatory factor analysis methods (Joreskog and Sorbom,

1981) are to be used to test hypotheses about the causal linkages of hypothetical variables.

To complement these two analyses of property level data, an analysis of 1970–1980 changes in the average socio-economic development (SED) levels of the 89 municipios of the region is also to be conducted, using data from IBGE's files. It is to follow the strategy outlined in the previous section of this paper. The first two projects are expected to provide clear evidence of the impact of the CEPEC/DEPEX system on agrotechnology, production, and the life conditions of the residents of the properties. The third project is expected to show the overall changes of the SED of the population of the region during roughly the same period. Together the three projects should provide convincing evidence of the impact of a technology generating center on the development of its target populations.

CONCLUSION

The two foregoing cases provide illustrations of research strategies for measuring development. The last case goes further than the first by illustrating a strategy for determining the effect of center for generation of publicly accessible new technologies on the development of the surrounding population. By going into such detail, these illustrations may provide a realistic notion of both the complexities and promises of modern socioeconomic research strategies applicable to the assessment of the impact of science and technology on development. The complexities include careful measurements of each variable in hypothetical causal sequences and careful modelling of the various causal hypotheses. They remind us that certain development-related variables may be more affected than others. Agro-technological research will affect agro-technological variables more than others, and may affect rural development variables more than urban variables. Similarly, we would get stronger effect of research on medical technology on health variables than we would on, say, agricultural development variables. And we would expect stronger effects of industrial technology centers on manufacturing than on general development. At least as important, it should show something of the quality of evidence concerning the developmental effects of science and technology that can be addressed. The promise of such research is that it can both provide convincing evidence of the value of investment in scientific and technological research establishments for developing nations and can help guide planning for such establishments.

Taken together, the two main sections of the paper may provide suggestions as to the kinds of evidence that it now seems feasible to obtain regarding scientific research efforts in comparison with those of

technological research efforts, and, among the latter, the kinds of evidence that may be feasible, depending upon whether the outputs of the research agencies are open or closed. Perhaps most important of all the paper calls for the measuring of the effects of scientific research on the one hand or technological research on the other. To the extent that these distinctions are valid they may also have implications for the organization of the scientific and technological research efforts of developing nations.

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