The Development of Thailand's Technological Capability in Industry

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The Development of Thailand's Technological Capability in Industry

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Assessing Thailand's Technological Capabilities in Industry

(The Development of Technological Capability in Manufacturing: A Macroscopic Approach to Policy Research for Thailand)

by

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The Development of Technological Capability in Manufacturing: A Macroscopic Approach to Policy Research for Thailand

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Table of Contents

List of Tables

The notion of technological capability has gained broad acceptance within the community of scholars and practitioners concerned with Third World development. Nonetheless, certain of its more important implications have yet to find widespread practical expression. One such implication has to do with the appropriate focus of the formal science and technology (S & T) plans that are episodically promulgated in a number of countries. From the capability perspective, Third World technological development is a matter of acquiring the requisite capabilities needed to make effective use of existing technology through its assimilation and adaptation. This implies that S & T plans should emphasize issues pertinent to gaining mastery of conventional technology. In the past, S & T plans have typically not had this focus. Instead, they have generally been concerned with issues more appropriately addressed in the context of research and development (R & D) in technologically advanced countries. Moreover, with respect to the manufacturing sector, they have focused on specialized technological agents -- public R & D institutes, for instance -- rather than on individual producing firms, which are the primary actors in acquiring technological capability.

There is good reason to believe that more is involved here than a simple difference in perspectives about what drives -- or ought to drive -- Third World technological development. Most of our knowledge about the acquisition of technological capability comes from microscopic empirical research on the internal workings of manufacturing enterprises. This is natural given that fundamental issues related to capability acquisition can only be comprehended in the microcosmic realm. But it is, at best, very difficult to fit the findings of microscopic research into the inherently macroscopic orientation of S & T planning. It is far easier to maintain the appearance of comprehensive scope and systematic formulation by concentrating, for example, on various aggregate indices of ostensibly crucial inputs and outputs. Plans require clear analytical frameworks in which to be formulated.

It is doubtful that there will be a widespread change in the focus of formal S & T planning for the manufacturing sector until there is a generally accepted framework for systematically incorporating the microscopic issues of capability acquisition into the macroscopic orientation of S & T planning.

This paper is about a major research study in the area of S & T planning for industry that was focused on capability issues. In this study, which took place over an eighteen-month period, twenty Ph.D. level economists and technologists (engineers and scientists) collaborated under the auspices of the Thailand Development Research Institute to seek answers to the following questions: How well do key industries in Thailand utilize technology? How does government policy, including the activities of public entities, affect its utilization? What new policies or changes in existing policies, if any, would enhance the utilization of technology? The first question consumed much of the researchers' effort, for in answering it they gave quantitative expression -- in the form of numerical scores -- to their assessments of the capabilities of a widely diversified sample of manufacturing firms in Thailand. In this paper we present the methodology that was used in analyzing the capability scores and we demonstrate the kinds of answers that can be obtained using it. To our knowledge, the work reported here marks the first occasion that such scores have been subjected to a reasonably thorough statistical analysis.

The scoring procedure and the statistical analysis, taken together, constitute a capability-focused, macroscopic approach to policy research. We have several purposes in exposing it: to elicit peer review of its utility; to state some seemingly important lessons that were learned in following it; and, to provoke discussion about how systematically to incorporate capability issues into S & T planning for the manufacturing sector. The paper is organized as follows: Necessary details about the scoring procedure and the sample of firms are given in section 1. The statistical analysis is described in section 2, and a few salient findings from that analysis are presented in section 3. Some methodological reflections are offered in section 4. In the appendix we amplify our reflections by stating an alternative, microscopic approach. Readers who wish to concentrate on essentials may do so without too much loss of substance by reading all of section 1, the introductions to sections 2 and 2.3, and all of sections 3 and 4.

1 Ingredients of the Macroscopic Approach

The research was centered on three technological areas: biotechnology (hereafter referred to as BioTech); electronics & information technology (ElecTech); and materials technology (MatTech). Technological capabilities in these areas were evaluated using a generalization of a method employed, but never to our knowledge formally published, by Frederick Moore and various colleagues in the World Bank's operationally oriented work on industry.1/ Firms were numerically scored with respect to their capabilities in some twenty fields of technological activity. Without going into the actual details of how the scores were determined, this section of the paper discusses the principal ingredients of the approach used in the research.2/ As will be observed, the particular ingredients employed in this study have a few potentially significant flaws that are not inherent in the general approach.

1.1 Technological Capabilities

Technological capability scores were awarded on the basis of evaluations made during plant visits by members of the respective area research teams. The scoring was done jointly by economists and technologists familiar with the particular industry in Thailand and in general. The scores reflect their attempt to consolidate a good deal of both objective and subjective information into coherent indices of firms' abilities in utilizing technology across a number of dimensions pertinent to the transfer, assimilation, and adaptation of industrial technology.

All three area research teams conceived of technological capabilities as being of four different kinds: operative, adaptive, innovative, and acquisitive.3/ Operative capabilities pertain to production knowhow. Adaptive and innovative capabilities relate to technological efforts that are central to the effective assimilation of technology and to its simultaneous cum subsequent adaptation to better fit local circumstances. Neither is to be understood in terms of research and development on the global frontier of technological change. Rather they are to be understood in terms of activities associated with technological development that takes place through transfers of technology complemented by indigenous efforts of assimilation, adaptation, and extension.4/ Acquisitive capabilities, in turn, relate to the ability to search for, assess, and transfer technology.

Notwithstanding their agreement regarding broad types of capability, the three area teams did not work with a common set of individual capabilities. The BioTech and MatTech teams each distinguished among twenty differentiated capabilities, but the two sets of capabilities are not identical. The ElecTech team employed only eighteen capabilities. For this reason, as well as for another discussed below, a rather different grouping scheme was used in the statistical analysis. This scheme was designed to achieve greater uniformity among the areas, thereby to facilitate common analysis in terms of several 'aggregate' capabilities. The scheme is shown in Table 1, which also identifies the various technological capabilities that were defined and scored by each area team.5/ Owing to definitional differences across areas, some individual capabilities in each area could not meaningfully be included as components of one or another aggregate capability; that is, they could not be included without undue sacrifice of comparability across areas. Thus some individual capabilities are considered as being 'related to' instead of 'included within' particular aggregate capabilities.

[Table 1 about here.]

The first four aggregate capabilities appearing in the table -- capabilities in production, minor change, major change, and investment -- are respectively akin to the area teams' clusters of operative, adaptive, innovative, and acquisitive capabilities. However, there are some pronounced differences between the two groupings, which is why other labels are used for the aggregates employed in statistical analysis.6/ Some of these differences are associated with the designation of a fifth aggregate which includes three 'capabilities' that were commonly identified and defined across all the areas -- training, R & D, and maintenance. These are not, strictly speaking, capabilities in the sense of reflecting ability in using resources. Rather, given the way they were defined and scored, they reflect capacities in the sense of resource endowment. Hence their segregation into a separate aggregate, technological resources. (For expositional convenience, 'technological capabilities' is the general term that is used throughout this paper to refer to all scored capabilities and capacities.)

As regards the difference between minor and major change: Minor changes affect neither the basic product mix being produced nor the basic production methods being used. They relate to such things as design and quality changes in existing products and changes in operating practices (as distinct from the basic methods which are embodied in core capital equipment) that might entail modifications in existing equipment or the addition of ancillary equipment. Major product changes substantially affect the product mix, for example by the addition of a product that is obviously or substantially differentiated from those already produced. Major process changes similarly substantially affect the basic production methods, for example by changing the technique or by internalizing some previously hired out activity. With respect to the capabilities for both kinds of change, it is very important to recognize that their scoring was based on evidence of actual changes having been made. The R & D capacity-not-capability, in contrast, was scored on the basis of R & D budget, staff, facilities, and the like.

The scoring scales that were used by the area teams are given in Table

2. It is to be noted that the MatTech team used an ostensibly quite different scale, one that places considerable weight on technological self-sufficiency at the firm level. The scale has considerable merit insofar as their scores have somewhat more objective content than do those in the other areas. However, there is absolutely no good reason to think that firms should be technologically self-sufficient. Thus, to the degree that they in fact do reflect technological self-sufficiency at the firm level, the MatTech scores have no prescriptive significance. That is, there is no reason to associate higher scores with economically (or socially) more desirable results. But, for a different reason (which also pertains for MatTech), the same caveat is equally relevant to the scores in BioTech and ElecTech.

[Table 2 about here.]

Two distinct aspects were mixed in scoring firms' technological capabilities. Economists make a clear distinction between choice of technology and the efficiency with which technology is utilized. In the context of the present research this translates into a distinction between the level of sophistication (relative to the global frontier) of the technology in use and the capability with which that technology is employed. These aspects were not systematically separated in the scoring by any area research team, as an economist would strongly argue they should have been, except perhaps in those industries -- like computer hardware -- where international competitiveness is clearly contingent upon using frontier technology. There is no a priori reason to think that only the most sophisticated technologies are appropriate to Thai industry; in fact, all the a priori reasons go the other way. High levels of efficiency or capability, on the other hand, are by definition -- assuming some care in the definition, and the measurement -- desirable.

In sum: the capability scores are biased estimates with respect to the measurement of capabilities cum capacities per se. The degree of the bias depends on the respective weights placed on capability and sophistication in the researchers' scoring.7/ Unfortunately, it is not possible to state these weights. However, the bias that is present in the absolute values of the scores does not necessarily affect the relative values obtained when scores are considered in comparison to one another. Intra-firm comparisons (across capabilities for one firm) and inter-firm comparisons (across firms for one capability) are biased with respect to indicating differences in capabilities cum capacities only to the extent that sophistication levels differ intra- and inter-firm respectively.8/ Since most of the analysis that follows is (explicitly or implicitly) concerned with relative values, it is at least possible that the bias has minimal consequences for the analysis.9/

There is one more aspect that is central to comprehending the meaning of the capability scores. In a word -- they measure Thai capabilities. Only insofar as a firm's personnel are Thai do the scores measure the firm's technological capabilities. In particular, scores for foreign-owned firms reflect the capabilities of the Thai nationals employed in those firms rather than the capabilities of the firms per se. As a consequence, the scores are especially relevant to gauging a central element of the effectiveness with which foreign invested firms transfer technology.

Given the crudeness inherent in scoring broad capabilities and the flaws in the scoring done for this research, it is clearly warranted to be somewhat doubtful about the utility and validity of the scores. In particular: What does a score of, for example, 3 really mean? Doubtless the scorers know, but they were generally unable successfully to communicate the full or precise meaning to others not intimately involved in the scoring; perhaps this is inherent in the nature of quasi-quantitative cum quasi-qualitative scoring. However, the tacitness of the absolute scores is not sufficient cause seriously to suspect the validity of the relative scores among capabilities and across firms. At the very least, the relative scores and the implications from the patterns contained within them merit serious attention. Continued skepticism is warranted, but not at the expense of carefully considering the findings from the scoring exercise.

1.2 Firm Characteristics

Table 3 states the industries that were investigated in each area and indicates the principal activities or products that were covered in each industry among the surveyed firms. The unit of observation was a firm's activities in a particular industry. Nonetheless, for expositional simplicity, 'firm' is the term used throughout to refer to the unit of observation. But it should be understood that the sample includes multiple observations for a few firms with activities in several of the industries studied. In turn, some of the firms had activities in other industries not covered in the survey. All told, the data set consists of 119 observations pertaining to the activities of more than one hundred firms in eighteen industries; literally, not just figuratively, the products span the range from chicken feed to microcomputers.

[Table 3 about here.]

The sampling frame for selecting firms was in principal that of a stratified random sample, though the MatTech research team purposefully chose to concentrate on technologically more advanced firms.10/ There are two reasons for saying "in principal." First, there was no attempt to achieve an evenly balanced sample (or, in technical jargon, a proportional sample design) across the characteristics considered as being relevant to the stratification. Second, some of the randomness in the researchers' selection was undoubtedly destroyed by purposive self-selection among the firms that chose not to participate in the survey; technologically weaker firms were the most likely to refuse participation.

Table 4 gives the typology, apart from industry membership, used to stratify the samples and to classify firms in the statistical analysis; Table 5 shows the samples' composition in terms of the typology. Five attributes were distinguished: industry; size; nationality of ownership (and, in the case of

BioTech and MatTech, of management); market orientation of sales; and BoI -- Board of Investment -- promotional status. The characteristics included under each non-industry attribute are as follows:

- size: large, medium, small;
- ownership cum management:
  for ElecTech -- Thai, joint venture, foreign subsidiary;
  for BioTech and MatTech -- Thai owned, foreign owned and Thai managed, foreign owned and foreign managed;
- market orientation: principally export, both export and domestic, principally domestic;
- BoI promotional status: no, does not receive BoI promotional incentives; yes, receives BoI promotional incentives.

It is to be noted that precise definitions of the size, ownership, and market orientation characteristics differ among the areas. Some of these differences -- those with respect to size, for example -- largely reflect legitimate, well-considered distinctions among the areas. Others reflect either ad hoc'ery or problems in gaining access to data. When data are pooled across areas for purposes of statistical analysis, these differences are assumed to be inconsequential except with respect to ownership cum management, where two separate ownership attributes -- one specific to ElecTech, the other specific to BioTech and MatTech together -- are used.

[Tables 4 and 5 about here.]

The foregoing typology reflects a number of underlying hypotheses about the nature of markets for technology. One is the expectation that large firms on average possess greater technological capability across the board than do small firms. The argument here concerns factors on both the demand and supply sides. On the demand side, the public good aspects of technology operate to a lesser degree for large firms. Similarly, being large, they may be better able to internalize resources necessary for the effective articulation of demand for technology than are small firms. In turn, there are many reasons to expect that larger firms have easier access to the supply of technology, in particular to foreign technology markets. The policy implication of this hypothesis -- if true -- is that technology markets are more likely to fail where small firms are concerned and, correspondingly, that government action to facilitate small firms' access to technology is particularly likely to be warranted.

Another set of hypotheses relates to differences in capabilities between Thai and foreign firms. ('Foreign firms' is used consistently throughout this paper to include all firms not classified as Thai with respect to their ownership.) For much the same reasons that large firms are expected technologically to outperform small firms, foreign firms can be expected to have higher production capability than Thai firms. However, insofar as this difference is grounded in dependence upon the capabilities of expatriate personnel or of the overseas parent, foreign firms may have lesser Thai capabilities in other areas. Some analysts do perceive reasons to expect them to have fewer technological resources and lesser change capabilities, especially in regard to adapting technology to local circumstances.

Export markets are generally considered to be more competitive than are domestic markets. Correspondingly, firms that export much of their output probably have greater motivation, in the form of competitive pressure, to achieve high levels of technological capability. Moreover, they must necessarily meet world standards of quality in relation to price. These considerations lead to the hypothesis that export-oriented firms have higher capabilities than firms whose sales are oriented toward the domestic market. In turn, just as it is difficult to know what to hypothesize about medium size firms relative to large and small ones, so it is rather hard to form expectations about firms that are both export- and domestic-market-oriented relative to those that sell primarily in one or the other market. However, there are reasons to think that they would have the highest capability among firms classified by market orientation. As exporters, they face the competitive pressure of world markets; but, as sellers on the domestic market, they also have motivation -- probably much greater than that of a wholly export-oriented firm -- to adapt technology to local circumstances. With both factors at play, they may technologically outperform firms for which only one of the factors is particularly relevant.

, As regards the impact of BoI promotion: Because it is ostensibly granted to firms in infant industries where the acquisition of technological capability is expected to be particularly costful, one might hypothesize that BoI promoted firms have less technological capability, at least in production, than do non-promoted firms. However, if BoI promotion succeeds in its objectives, it is only those BoI promoted firms that started operation relatively recently (and so remain in their infancy) that would have relatively low capabilities. But even for them, another aspect of BoI promotion implies, if anything, the opposite hypothesis. BoI promotional incentives include a number that give promoted firms far easier access to foreign technology markets than is typically enjoyed by non-promoted firms. For example, BoI promoted firms have strong preferential rights to import foreign technical assistance in the form of expatriate personnel. To the degree that these firms are able to assimilate technology transferred by foreign technical assistance, they should therefore have higher capabilities.11/

It must be noted that separate information was not obtained about what economists would consider the single most important firm characteristic, namely economic (or social) profitability. The reason is straightforward: the researchers believed that any questions they might ask that were obviously and immediately pertinent to gauging a firm's profitability would only elicit information meant to be intentionally misleading. Judgmental scoring, like that used to assess technological capabilities, offers an alternative -- albeit imperfect -- approach to measuring profitability. Indeed, one of the common individual capabilities, that in operation (under production capability), can legitimately be considered a proxy -- although a somewhat imperfect one -- for financial profitability. It is not also a proxy for economic profitability insofar as some firms may not have opted for the economically (or socially) optimal choice of technology and insofar as market prices diverge from economically appropriate (efficiency or shadow) prices. One can only wish that the researchers had purposefully applied judgmental scoring to provide a separate indicator of economic profitability.

2 Statistical Analysis of Capabilities

There are three parts to the statistical analysis of the capability scores. The first uses dummy-variable regression estimation to do two things simultaneously. One is to remove the effect of sampling bias to obtain estimates of average scores among all firms within the corresponding populations. (The sampling bias at issue here is that due to the unevenly balanced composition of the samples in each area with respect to firm characteristics of possible consequence for technological performance.) The other is to estimate score differentials for firms of different types. These differentials are differences between estimates of two average scores: one is an average score for all firms in the population; subtracted from it is the average score for all firms of a particular type in the population.

To the extent that they can be used to examine the validity of hypotheses that imply different kinds of technological behavior among different types of firms, estimates of score differentials are very useful when trying to explain observed levels of technological capability. But there are other, often more direct, ways of attempting to explain observed capability levels. The second and third parts of the analysis use regression estimation to explore two of them. One seeks to relate capability levels to particular attributes of the technologies being employed. Insofar as proficiency levels are systematically related to technological attributes, this kind of analysis can provide diagnostic information that is highly pertinent for describing and understanding the particular strengths and weakness of technological development processes. The other examines various relationships among the technological capabilities themselves. Insofar as some critical capabilities derive from or are dependent upon others, this genre of analysis can lead to important inferences about deficiencies in the way that technological development has been managed over the past.

Before turning to the analysis of the capability scores, it is warranted to examine some salient statistics concerning them. Statistics for all three technological areas are given in Table 6. Those appearing in the first, three-row set of values are undoubtedly more reflective of differences in scoring approaches among area teams than of real differences among technological areas. In turn, it is interesting to observe from the second set of values that, except in BioTech, differences among firms contribute less -- indeed, substantially less -- to the total variance of the scores than do differences among capabilities. The high degree of correlation (third set of values) that is present among the scores for different capabilities is striking, but the correlations are neither so great nor so uniform (when one examines them in detail) as to suggest failures to discriminate among capabilities in the scoring. The fourth set of values shows that aggregation -- simple averaging was used -- of individual capabilities results in substantial loss of information; but, as will be seen in section 2.1.3, the loss is not so great as to make the aggregate capabilities meaningless.

[Table 6 about here.]

In part to simplify the analysis, but more importantly to test for possible differences in the association of capabilities with non-industry attributes of the firm, the area samples were pooled into a single sample. As indicated above, there is no reason to believe that the three area teams scaled their scoring in the same way with respect to average and standard deviation. Thus, when combining scores from the areas to obtain the pooled sample, standardized rather than absolute scores were used. Let:

$r_{a,i,j}$ = in area a, the i'th firm's raw score with respect to the j'th capability;

$s_{a,i,j}$ = the corresponding standardized score;

avg_a = the average of the $r_{a,i,j}$ scores for all firms i and capabilities j in area a; and,

std_a = the corresponding standard deviation of the $r_{a,i,j}$ scores.

Then: $s_{a,i,j} = [(r_{a,i,j} - avg_a) / std_a]$. (1)

The last, two four-row sets of values in Table 6 pertain to the standardized scores for aggregate capabilities and include the pooled sample. These values can be compared with comparable values for individual capabilities in the three area samples to see how aggregation and pooling affect several indices of interest.

2.1 Associations with Attributes of the Firm

This section discusses the estimation of population average scores and sub-population score differentials; both were estimated simultaneously. First, the general regression model is given. Then the alternative specifications that were used in sensitivity analysis are discussed. Lastly, the results of that analysis are summarized. Presentation of the estimates is deferred to section 3 where policy-relevant findings discussed.

2.1.1 Attribute Regression Model 12/

The same general, dummy-variable regression model was used for all of the 'attribute' regressions that are discussed in this section. It is stated below:

$$y_i = a + \sum_{M} \sum_{J_m} (b_{j_m} d_{j_m,i}) + c x_i + e_i,$$ (2)

for all i in I; where:

$$\sum_{J_m} b_{j_m} = 0, \text{ for all m in M;}$$ (3)

y_i = the i'th firm's score with respect to a designated capability;

$d_{j_m,i}$ = the value for the i'th firm of the dummy, or attribute, variable that is associated with characteristic j_m:

$d_{j_m,i}$ = 1, if the firm has the characteristic;
= 0, if the firm does not have the characteristic;

x_i = the i'th firm's age;

e_i = the error term that is associated with the i'th firm;

I is a designated sample of firms; i denotes an individual firm;

M is a designated set of attributes; m denotes an attribute -- industry, or market orientation, for example;

J_m is the set of characteristics that constitutes attribute m; j_m denotes a characteristic that is included within that set -- aquaculture within industry, or export within market orientation, for example;

a, b_{j_m}, and c denote parameters.

In equation (2) above, a is the constant term. Its estimated value serves as the estimate of the average capability score in the population (from which the sample is drawn). The parameter b_{j_m} is the score differential, or 'own effect,' that is associated with a firm's having the characteristic j_m. In other words, it is the average effect of having that characteristic. The terminology, 'own effect,' comes from the analysis of variance, which is closely related to the estimation of regressions of the form given above.

Equation (3) imposes a normalizing condition in the form of a statement that the sum of the own effects for the characteristics of any attribute must equal zero. This condition merely stipulates that each attribute has no overall effect; that is, that each is 'on balance' -- or on average across all the characteristics included within it -- neutral.

For certain sample designs, the estimated values of the parameters have a straightforward interpretation in terms of sample and sub-sample averages. Suppose, for example, that the number of observations in each cell is the same for all cells. (A "cell" refers a particular combination of characteristics across all attributes.) To keep matters simple, further suppose that there are no non-attribute variables in the model. Then:

- the estimated value of a is equal to the average score in the sample;
- the estimated value of b_{j_m} is equal to the average score for all observations having characteristic j_m minus the average score in the sample.

Alternatively, and somewhat less restrictively, suppose that the number of observations for each characteristic of an attribute is the same, which yields a 'proportional' sample design.13/ The only difference this makes in the foregoing statement of estimated values is that 'the simple average of the cell means' replaces 'the average score in the sample.' As regards non-attribute variables: their inclusion simply leads to the adjustment of the averages to reflect their estimated impact, which is assumed to be linear.

Sample bias exists when the model includes more than a single attribute and the sample design is nonproportional; in such cases, parameter estimates cannot be interpreted in terms of sample and sub-sample averages. All of the samples employed here -- those for BioTech, ElecTech, and MatTech, as well as the pooled sample -- are nonproportional. More than this, many of their cells are empty. Some of these cells probably have no members within the population. However, the large number of empty cells is importantly due to small sample sizes relative to the numbers of attributes and characteristics included in the analysis.14/ The presence of so many empty cells has a serious consequence: the parameter estimates are far less reliable than they would otherwise be.

The attribute variables that appear in the preceding statement of the model cannot be directly used in regression estimation. This is because, with them defined as they are above, the complete set of variables in the model does not constitute a linearly independent set. Thus a consistent but distinct, reduced set of variables for each attribute has to be constructed for use in estimation. This is done by using the normalizing condition in equation (3) both to express the b_{j_m} coefficient for one characteristic of an attribute in terms of the other characteristics and to remove the corresponding attribute variable.

2.1.2 Alternative Specifications

There is necessarily a good deal of uncertainty about the proper specification of the attribute regressions. Underlying equation (2) are the assumptions that own-effects are linearly additive and that there are no peculiar interaction effects among characteristics of different attributes. Are these assumptions appropriate? Other questions also arise: Can individual capabilities legitimately be aggregated? Is it warranted to pool the area samples? Are all the attributes necessarily relevant? No attempt was made to answer these questions in way that would formally or definitively resolve the uncertainty. Instead, a systematic series of sensitivity analyses was conducted, with particular attention being paid to the sign and significance of the estimated score differentials from different specifications. All of the specifications employed in these analyses include both the constant term and the age variable.

The relative merit of the additive specification was examined using the ElecTech sample (only) in early experimentation with a multiplicative specification in which the natural log of the scores replaced the raw scores as the dependent variable. The general pattern of coefficient signs and significance was quite similar to that in the regressions using the raw scores. The additive specification was chosen for use in all subsequent analysis because it gave generally higher R-squared's.

The possible existence of peculiar two-way (only) interaction effects among characteristics was investigated somewhat more systematically at a later point in the analysis.15/ The investigation focused on adding interaction effects to the specification of the ALL Pool regressions discussed below. Separate regressions were estimated for each of the six possible pairs of attributes obtained when the industry attribute is omitted from consideration; interactions between industry and other attributes were not examined. It was determined that interaction effects are relatively unimportant by noting that:

their introduction led to relatively few changes -- vis-a-vis the corresponding regressions in which they did not appear -- in the sign and significance of the own-effect estimates; only a few of the interaction effect coefficient estimates were significant; there did not appear to be any clear or strong pattern to the results that came from introducing interaction effects.

To address the other questions about proper specification, four distinct specifications were estimated; three for each aggregate capability and one for each individual capability:

For the aggregate capabilities, where raw and standardized scores respectively refer to the simple average of raw and standardized scores for the corresponding individual capabilities --

- ALL Pool regressions: These are estimated for the pooled sample, so the dependent variable is a standardized score. The independent variables include three sets of industry attribute variables, one set for each area;16/ one set of dummy variables for each of the other attributes; and the age of the firm.

- ALL Area regressions: These are estimated separately for each area sample, so the dependent variable is a raw score. The independent variables are the same as those in the All Pool regressions except that only the attribute variables for the corresponding area are included.

Sensitivity to the pooling of areas was analyzed by comparing estimates from the ALL Pool regressions with those from the corresponding ALL Area regressions.

- ONE Area regressions: These are estimated separately for each attribute and area sample; the dependent variable is a raw score. The independent variables, apart from the constant term, include only those for one attribute.

Sensitivity to the inclusion of one versus all attributes was analyzed by comparing estimates from the ALL Area regressions with those from the comparable ONE Area regressions.

For the individual capabilities --

- Regressions comparable to the ALL Area regressions: Separate regressions identical in specification and sample to the ALL Area regressions were estimated for each individual capability either included in or related to each aggregate capability.

Sensitivity to aggregation was analyzed by comparing estimates from these regressions with those from the ALL Area regressions for the corresponding aggregate capabilities.

The objective of sensitivity analysis across these specifications was to find the most all encompassing specification that seemed best to 'fit the facts.' That is, in order to keep the analysis relatively simple, it was decided to employ a uniform specification for all of the aggregate capabilities and, if pooling appeared to be inappropriate, areas. The hope was that the ALL Pool regressions would be the chosen specification. This hope was fulfilled, as is summarily indicated in two tables that are discussed immediately below.

2.1.3 Overview of the Results

Tables 7 and 8 report statistics about the extent of sign agreement among the different estimates of the parameters and about the extent to which the estimates reveal significant associations. Table 7 relates to the estimates from the ALL Area regressions for aggregate and individual capabilities. It is germane to assessing sensitivity to aggregation. Table 8 pertains to estimates from the ALL Pool and ALL as well as ONE Area regressions for the aggregate capabilities. It is relevant to gauging sensitivity to pooling and to the inclusion of ONE versus ALL attributes.

Consider first Table 7 and the issue of aggregation. For each attribute there is one, three-line cell for each aggregate capability and for all of the aggregate capabilities considered together.17/ The entry on the first line (acronym A.AS.) indicates the percentage of cases in which the algebraic sign of a parameter in the ALL Area regressions for the individual capabilities agrees with the corresponding parameter's algebraic sign in the ALL Area regression for the corresponding aggregate capability (i.e., that in which they are included or to which they are related). Thus, the first entry in the top-left cell of the table, for example, indicates that in 80 percent of the cases, the indicated direction (negative or positive) of the association between scores for individual production capabilities and the industry to which a firm belongs is the same as that between the aggregate score and industry membership.

[Table 7 about here.]

As can be seen from the entries in the first line in the last row of cells, there is a high degree of sign agreement across all attributes and aggregate capabilities. This result suggests -- and a careful perusal (including attention to the significance of comparable parameter estimates of different sign) of the underlying estimates confirms -- that it is not illegitimate, at least not with respect to coefficient signs, to aggregate the individual capabilities as is done in the following analysis. This is not to claim that the aggregation scheme in Table 1 is in any formal sense an optimal one. Nor is it to say, in seeming contradiction to information in Table 6, that aggregation does not hide information of considerable interest about differences among individual capabilities. It is rather to affirm that one can meaningfully reduce the number of dimensions in which capabilities are considered without doing too much violence to the underlying reality.

Turn now to Table 8, which is similar in design to Table 7, the only difference being that the cells for each aggregate capability contain four entries. Recall that this table is relevant to judging whether it is warranted to pool the samples and to focus on estimates from the specification that includes all attributes together. Entries on the first line of each cell indicate the percentage of cases in which the algebraic sign of a parameter in the ALL and ONE Area regressions for an aggregate capability agree with the corresponding parameter's algebraic sign in the ALL Pool regression. The overall extent of sign agreement comparing these specifications is again quite high. This implies -- and a careful perusal (including, as before, attention to the significance of comparable parameter estimates of different sign) of the underlying estimates confirms -- that it is not illegitimate, with respect to coefficient signs, to focus on the estimates from the ALL Pool regressions. This is not to suggest that these estimates are the 'right' ones in all cases. Rather it is to indicate that one can legitimately take the ALL Pool results as a starting point in looking for any regularities present in the underlying data, qualifying particular regularities so found only where there appears to be strong disagreement between them and the evidence from other specifications.

[Table 8 about here.]

Consider next the entries on the second and third lines of each cell in Tables 7 and 8. In the work underlying these entries, parameter estimates were identified as being significant 'with respect to the sample' (S.S. is the acronym in the tables) if they exceeded their respective standard errors; 'with respect to the population' (S.P.), if they were statistically, significantly different from zero, using a t-test, at the 0.10 level of significance. The notion of significance with respect to the sample is an ad hoc way of distinguishing estimates that imply seemingly meaningful differences among firms within the sample, if not necessarily within the population. In turn, it should be recognized that the 0.10 significance level used in evaluating significance with respect to the population is the lowest level of significance conventionally employed in statistical work such as this.18/

The entries for sample and population significance indicate the number of correspondingly significant, conformably-signed parameter estimates as a percentage of the total number of comparable estimates. Significant estimates from secondary regressions are included in the count only if they conform in algebraic sign with the primary regression estimates.19/ In Table 7, relevant estimates are those from the ALL Area regressions for aggregate (primary) and individual (secondary) capabilities; in Table 8, those from the ALL Pool (primary) and ALL as well as ONE Area (secondary) regressions for aggregate capabilities.20/ The information given in these entries indicates that there are a number of seemingly significant associations between technological capabilities and firm attributes. From the last row of cells in each table, one sees that industry, size, and ownership appear to matter more than do market orientation and promotional status. One also finds that age is significant with respect to the population in relatively few cases. In turn, from the next to last column of cells, one observes that associations between non-industry attributes and capabilities are strongest in the realms of production and investment.

Though it has the real virtue of being readily accomplished, the foregoing sensitivity analysis does not constitute a formal means of comprehensively rigorous hypothesis testing. The rigorous way to test the significance of an individual attribute is to use analysis of covariance, which involves computing an F-statistic from two distinct regressions, one that includes the attribute and another that does not.21/ Such an analysis was conducted for each aggregate capability using the pooled sample. Its execution entails an additional set of regression specifications:

- OMIT regressions: These are identical to the ALL Pool regressions except that they omit variables and parameters associated with one attribute.

With the ALL Pool regression considered as the 'unrestricted' model, an OMIT regression constitutes the 'restricted' model in which the omitted attribute is assumed to exercise no influence. Since both regressions include all other attributes, covariance analysis using them tests the significance of the omitted attribute while controlling for the possible influence of every other attribute.

The resulting F-statistics are given in Table 8, in the entries on the fourth line of the cells for each aggregate capability. (Also given, in the All Other Attributes column, are F-statistics from comparing ALL Pool regressions with regressions that omit all of the non-industry attributes.) These statistics imply some seemingly pronounced dissimilarities among capabilities in the pattern of associations between capability levels and firm attributes. Production capability is far more strongly associated with the attributes than is any other capability. Size and, to a lesser degree, ownership as well as promotional status are the significant attributes where it is concerned. In contrast, major change capability appears to be randomly distributed with respect to non-industry attributes, since it is significantly associated with none of them. However, minor change and investment capabilities are significantly associated with size, while technological resources are significantly associated with ownership and promotional status. The most striking result concerning the non-industry attributes is the apparent lack of any significant associations involving market orientation. In turn, industries within areas do not appear to differ appreciably in their levels of production capability, but they do seem to differ substantially with respect to the other capabilities.

As was stated above, the preceding analysis controls for the possible influence of all other attributes when testing the significance of any one attribute. Parallel analyses for individual non-industry attributes were conducted controlling for all other non-industry attributes and for industry attributes only. The results gave no clear reason to qualify any of the statements in the last paragraph; in particular, in the small number of cases where one of the parallel analyses gave a contradictory significance indication, the other gave a confirming indication.

The covariance analysis could have been carried further, by systematically controlling for additional subsets of other attributes and by methodically testing the significance of alternative subsets of characteristics for attributes having more than two characteristics. However, this was not thought to be warranted in the context of an initial exploration of the capability scores. Thus, for this part of the statistical analysis, we now have only to present the parameter estimates, which is done in section 3.

2.2 <u>Associations with Attributes of the Technology</u>

The statistical analysis in the section above looked for associations between capabilities and various attributes of firms. Another potentially useful approach is to seek regularities in relationships between capability levels and particular attributes of the technologies being employed. Thanks to the efforts of the BioTech team, this approach can be explored with respect to one attribute in one area.

During the course of their work, that team developed the hypothesis that technological capabilities among firms in the BioTech area are inversely (or negatively) related to the sophistication of the technology in use. To examine its validity, linear regressions were estimated in which the dependent variable is an industry's (estimated population) average score for an aggregate capability and the independent variable is its overall average score with respect to the sophistication of the technology in use. The latter scores are shown at the bottom of Table 9, which gives the full set of scores for the technologies in use by the sampled firms in the BioTech area. The scoring scale that was used is shown below:22/

5: Equals MOST ADVANCED used in industrial countries;
4: Equals AVERAGE used in industrial countries;
3: BELOW AVERAGE in industrial countries, HIGHER than for most local firms;
2: WELL BELOW AVERAGE in industrial countries, EQUALS local average.
1: BELOW local average.

[Table 9 about here.]

Separate linear regressions were estimated for each aggregate capability using population average score estimates from the ALL Pool and ALL BioTech attribute regressions. The sample for these regressions consists of the eight BioTech industries. It obviously would have been preferable to examine the relationship at the firm, rather than industry, level. But this was precluded by the way the BioTech team assembled their information in the course of their work. In turn, it is important to recognize that the overall average sophistication scores do not incorporate any judgment about the relative sophistication of the different technologies (indicated in row titles in Table 9). This means that they do not fully capture differences (or, for that matter, similarities) among industries with respect to the overall sophistication of the technology they use.

Table 10 gives the regression estimates. The slope coefficients are negative -- implying an inverse relationship -- except in the case of technological resources. However, only two of the negative coefficients are significant (and that only at the 0.10 level). Thus one can at best say that the evidence is at most consistent with the hypothesis of an inverse relationship.

[Table 10 about here.]

It is not contrary to the BioTech team's hypothesis to find a positive relationship for technological resources, since they denote capacities rather than capabilities. In turn, since one would expect -- other things being equal -- a positive relationship between the sophistication of the technology and the technological resources needed to employ it, the fact that this relationship is positive is one of many small pieces of concrete evidence in favor of the meaningfulness of the relative values of the capability scores. In a similar vein, the fact that the relationships for other aggregate capabilities are negative implies that the BioTech research team's scoring pertains more to capabilities than to sophistication of technology.23/

2.3 Relationships among Capabilities

The final part of the statistical analysis investigates whether relationships among aggregate capabilities that are known to hold in the medium-to-long run are present in the capability scores for firms of different types. These relationships embody the keys to achieving self-sustaining technological development. Insofar as they are found to be present, their presence enables one to go a considerable distance in explaining the observed levels of those capabilities that are importantly dependent upon other capabilities. Insofar as they are found to be absent, their absence indicates deficient management of technological development and implies poor economic performance in the future.

The focal relationships have been documented in previous research on the industrial sector in Thailand [Bell and Scott-Kemis (1987), Chantramonklarsi (1985), and Santikarn (1981)] as well as elsewhere in the Third World [Dahlman, Ross-Larson, and Westphal (1987)]. To summarize only the most pertinent findings concerning production capability: As Bell and Scott-Kemis clearly demonstrate, firms do not acquire a high degree of production capability without investing in the technological resources required for technological change activity. Moreover, as Chantramonklarsi shows with equal force, purposive efforts to acquire some proficiency in investment activity play a vitally important role in the acquisition of production capability. Additionally, as virtually all of the research done to discover the underpinnings of production capability indicates, technical efficiency in production cannot be achieved without engaging in substantial minor change activity. Comparable findings pertain to major and minor change capabilities; they too are critically dependent upon certain underlying capabilities and resources.

In short: The evidence about technological development in semi-industrial countries clearly indicates that the following relationships hold in the medium-to-long run:

$$Prodn = f\ (\ MajCh,\ MinCh,\ Invst,\ TecRe\ ); \quad (4)$$

$$MajCh = f\ (\ MinCh,\ Invst,\ TecRe\ ); \quad (5)$$

$$MinCh = f\ (\ Invst,\ TecRe\ ); \quad (6)$$

where f(...) denotes functional dependence, with all first-order partial derivatives being positive.24/ These relationships are arranged in a hierarchical order only for aesthetic cum expositional purposes. While one might investigate their presence in the context of a formal system of simultaneous or recursive equations, that is not done here. Instead, each relationship is examined separately. In addition, technological resources and investment capability are autonomous, or exogenous, with respect to both our discussion and the examination.

Equations (4) through (6) should be understood as expressing conditions that are more nearly necessary than sufficient in the medium-to-long run. Consider, for example, the relationship between production capability and technological resources: adequate resources are necessary for self-sustaining proficiency in production; but their mere presence does not insure proficiency, since they need not be used effectively. Moreover, in the short run, the conditions expressed by these equations are not even necessary. All of the evidence hastily summarized above pertains to the underpinnings of a high degree of proficiency that can be considered self-sustaining over at least the medium-run. There is no reason to think that firms cannot be relatively proficient in the short run owing to what is essentially good luck. This consideration is especially relevant here, where the analysis involves relative scores among firms that are typically not high achievers in regard to their capabilities. These considerations mean that the finding of weak relationships can be taken as indicative of poor technological strategies at the firm level. The term 'technological strategy' refers to a firm's ability to manage its technological development; in particular, to achieve self-sustaining proficiency on the basis of investments in underlying capabilities.

2.3.1 Capability Regressions

Regression analysis was used to examine the strength of the functional relationships among aggregate capabilities across different types of firms. Stated in linear form, and augmented to incorporate possible differences in the relationships among firms of different types, equations (4) through (6) have the following general form:25/

$$y_i = \underline{A} + \sum_m \sum_{J_m} (A_{j_m} d_{j_m,i}) + \sum_K (\underline{B}_k z_{k,i}) + \sum_K \sum_M \sum_{J_m} (B_{k,j_m} z_{k,i} d_{j_m,i}) + e_i, \qquad (7)$$

for all i in I; where:

$$\sum_{J_m} A_{j_m} = \sum_{J_m} B_{k,j_m} = 0, \text{ for all m in M, and all k in K;} \qquad (8)$$

y_i = the i'th firm's score with respect to a designated dependent capability;

$z_{k,i}$ = the i'th firm's score with respect to independent capability k;

K is a designated set of independent capabilities; k denotes a capability that is included within that set;

'Dependent' and 'independent' capabilities are designated as indicated in one of equations (4) through (6);

$d'_{j_m i}$, e'_i, I, i, M, m, J_m, and j_m remain as defined in equation (2);

$\underline{A}$, A'_{j_m}, $\underline{B}_k$, and B'_{k,j_m} denote parameters.26/

In equation (7): parameters $\underline{A}$ and $\underline{B}_k$ pertain to the relationship that exists 'on average' across all of the firms in the designated sample. Parameters A'_{j_m} and B'_{k,j_m} pertain to the difference between that relationship and the relationship that exists across firms having characteristic j_m; that is, these parameters express the 'partial' differential that is associated with the characteristic. Here 'partial' denotes controlled with respect to the other attributes that are included in the designated set of attributes, M. In turn, equation (8) imposes the requisite normalization conditions [see the discussion of equation (3) in section 2.1.1].

Values of R-squared from capability regressions for distinct sub-samples of firms provide measures of the strength of the functional relationships for the corresponding types of firms. Additional regressions must be estimated for whole sample in order to test the significance of possible differences in their strength among different types of firms. The various regression specifications are identified below, starting with those involved in the significance testing. All of the regressions use the pooled sample and the standardized scores. Two changes were made in the specification of the attribute variables to compensate for the fact that each characteristic is associated with several variables and parameters in equation (7). Industry attribute variables were replaced by area-specific dummy variables. In addition, the ownership attribute was reduced to two characteristics, Thai and foreign, so that a common set of attribute variables could be used for firms in all three areas.27/

Significance testing: The method employed here is essentially the same as that employed above in connection with the attribute regressions.28/ Analysis of covariance is used to test the significance of each attribute as a possible determinant of each functional relationship. This again involves computing F-statistics from pairs of distinct regressions estimated over the entire pooled sample. As is indicated below, the regression specifications differ only in the set of attributes designated for inclusion in the specification -- that is, they differ only in regard to the set M.

- *ALL* regressions: All attributes are included in the designated set, M.

- *OMIT* regressions: All attributes but one are included in the set.

With the *ALL* regression considered as the unrestricted model, an *OMIT* regression constitutes the restricted model in which the omitted attribute is assumed to exercise no influence. Here covariance analysis tests the significance of the omitted attribute while controlling for the possible influence of all other attributes.

- *ONE* regressions: Only one attribute is included in the designated set, M.

- *NULL* regressions: No attribute variables are included in these regressions.

With the *NULL* regression considered as the restricted model, a *ONE* regression constitutes the unrestricted model in which the specified attribute is assumed to exercise an influence. Here covariance analysis tests the significance of the specified attribute without controlling for the possible influence of other attributes.

R-squared determination: The different values of R-squared that are respectively associated with the distinct characteristics of a given attribute are obtained from regressions over mutually exclusive sub-samples. The regression specification does not include the given attribute in the set of attributes designated for inclusion. In turn, the sample is split according to the characteristics of the given attribute, so that each sub-sample consists only of firms that share the same characteristic with respect to that attribute. The choice of regression specification determines to what extent the R-squared's are controlled for the possible influence of attributes other than the given attribute, as is indicated below.

OMIT regressions: When the entire sample is split according to the characteristics of the excluded attribute, values of R-squared from these regressions over the sub-samples are controlled for the possible influence of other attributes.29/

NULL regressions: When the entire sample is split according to the characteristics of any attribute, values of R-squared from these regressions over the sub-samples are not controlled for the possible influence of other attributes.

2.3.2 Estimates of Interest

The top half of Table 11 gives the F-statistics that are relevant for determining significant differences in the functional relationships among different types of firms. Three sets of statistics are provided; the entries in the Attributes Controlled For column distinguish among the sets. The first set, which is controlled for all other attributes, is based on comparing the *ALL* and *OMIT* regressions. The second set, which pertains only to non-area attributes, is controlled for all other non-area attributes. These statistics come from comparing regressions that are identical to the *ALL* and *POOL* regressions except that both omit the area attribute. The third set, which is not controlled for other attributes, uses the *ONE* and *NULL* regressions. Statistics appearing in the All Other Attributes column are based on comparing the corresponding *ALL* regressions with regressions that omit all of the non-area attributes.

[Table 11 about here.]

Judging by the significance of the individual F-statistics, one can infer that most of the attributes do not exercise an important influence as determinants of the functional relationships for change capabilities. In the relationship for major change capability, only the area attribute appears to be unarguably significant, though at the 0.05 level; the size attribute is significant only when controlling for the possible influence of other attributes. In the relationship for minor change capability, area and market orientation are seemingly significant, the latter strikingly so. The results are largely inconclusive where production capability is concerned. All attributes appear to be significant at the 0.01 level when no other attributes are controlled for, but none are significant at even the 0.05 level when all other attributes are controlled for. There is far more ambiguity here than in the corresponding significance tests for the attribute regressions (see the discussion of Table 8 at the end of section 2.1.3). Also notable is the difference in the results for market orientation; it is seemingly insignificant in all of the attribute regressions but is arguably significant in the relationship for production capability and unarguably so in that for minor change capability.

Because of the potential effects of mis-specification from the inclusion of all other attributes in the *OMIT* regressions, the results with respect to production capability do not necessarily imply that no attribute is significant when considered in combination with other truly significant attributes. The attempt to identify truly significant attributes could have been carried further, by systematically controlling for alternative pairs, triples, quartets of attributes. But this was not done. The small number of observations in most cells, with many cells having no observations, makes it doubtful whether such a search would yield conclusive findings.

The analysis was, however, extended to conduct a partial search for redundant characteristics among attributes having more than two (i.e., three) characteristics. There is a redundant characteristic if the influence of any two characteristics is ostensibly identical. The search involved comparing three pairs of *ONE* and *NULL* regressions, one pair for each pair of the attribute's characteristics; each regression pair is estimated over the sub-sample of firms that have one or the other of the pair of characteristics. The null hypothesis of redundancy was accepted if the resulting F-statistics were not significant at the 0.05 level. On this basis, there is only one redundant characteristic among the attributes that are significant when not controlling for other attributes: there appears to be no significant difference between medium and small firms in the relationship for production capability.

As stated previously, it is differences in the strength -- measured by R-squared -- of the functional relationships among different types of firms that are the ultimate concern here. Before turning to the full set of R-squared values, it is warranted to look at estimates of the functional relationships over all of the observations in the pooled sample. The bottom half of Table 11 gives estimates from the *NULL* regressions. It will be observed that all of the regressions are highly significant, which does not -- of course -- imply that they need be equally significant when estimated for distinct sub-samples. All of the coefficients associated with independent capabilities in these regressions are positive except that for major change capability in the regression for productive capability. The negative coefficient is not necessarily indicative of anything other than the fact that major changes can be quite disruptive in the short run. Based on this consideration, it was decided to omit major change capability from the regressions for productive capability in the subsequent analysis.

Hereafter, all references to R-squared are to values adjusted for degrees of freedom, which can legitimately be compared across regressions having different numbers of observations and independent variables. The values for different types of firms, which are reported in the next section, were obtained from *NULL* regressions. This choice was dictated by the fact that some of the sub-samples have fewer observations than there are independent variables in the *OMIT* regressions. To investigate whether the *NULL* regressions appear to give robust results, R-squared values from them were compared with values from the *OMIT* regressions for minor change capability, where it is possible to estimate seven out of the total of ten regressions. The simple correlation coefficient between the two sets of seven R-squared values for the relationships involving minor change capability is .90, which suggests that the *NULL* regressions give reasonably robust results.

One additional consideration requires attention before the R-squared values can be presented. Apart from the one case already discussed, negative coefficients associated with independent capabilities have a clear meaning -- they imply poor management of technological development. However, inverse relationships between dependent and independent capabilities can spuriously elevate values of R-squared.30/ Thus it was decided to re-estimate any regression for which one or more independent capabilities had negative coefficients and to use the alternative regression for the reduced set of independent capabilities that gave the highest value of R-squared subject to the constraint that the chosen regression include the maximum number of all positively related (to the dependent capability) independent capabilities across the alternatives. Because virtually all of the negative coefficients in the original regressions are highly insignificant, the use of this procedure turns out not to make an appreciable difference. The simple correlation coefficient between the resulting values and the values of R-squared from the original regressions is more than .99 (comparing 30 values).31/

3 Some Salient Findings for Policy

Table 12 gives one way of summarizing both the overall results of most of the preceding analysis and some its implications for an understanding of technological dynamics in Thailand's industrial sector. It gives measures of aggregate capabilities, in the Scor (score) rows, and of the strength of the relationships among them, in the Crln (correlation) rows.

[Table 12 about here.]

The measures appearing in the Scor rows are from the ALL Pool attribute regressions. They pertain to standardized scores, which have an average across all firms and aggregate capabilities of virtually zero. Values are in standard deviation units, thus an estimate for the population average of 1.0 implies a value one standard deviation from the simple average of all the individual capability scores in each technological area respectively. Likewise, score differentials (given in the other columns, see below) are in standard deviation units.

The Scor values in the first column of numbers pertain to all firms; they are estimates of population average scores. It will be observed that capabilities are much stronger in production than in other aspects of technology utilization. In view of the long-run functional relationships that exist among capabilities, this does not auger well for the future, for it implies a failure to accumulate important, requisite underlying capabilities. Of particular concern in this regard is the relatively (and significantly so) low score for technological resources.

Values of the Scor measure in other columns are estimates of sub-population score differentials associated with the various characteristics.32/ Two Scor values are given for the ownership attribute: the top value is for ElecTech, the bottom for BioTech and MatTech combined; values shown for foreign ownership are simple averages over the two foreign characteristics. The adjectives, descriptive of the quality of the capability, that appear below the Scor values are an attempt to make their meaning more transparent. They basically indicate where each value falls among the quintiles of the distribution of all the score differentials reported in the table. The quintile breakdown was, however, adjusted to reflect major breaks in the distribution of the values.33/ 'GOOD' is applied to values in the highest adjusted quintile; 'good,' the next highest; and so on in the order 'AVERAGE,' 'poor,' 'POOR.' 'MIXED' indicates that there is considerable heterogeneity in the underlying estimates. It is applied only with respect to the ownership attribute, where -- as noted above -- all foreign firms have been combined together. The exclamation and question marks that appear below some of the words indicate whether the judgement of relative capability should be considered robust (i.e., with respect to alternative specifications of the underlying regression). Robustness was judged using information that underlies Table 8, which was discussed in section 2.1.3.

The measures appearing in the Crln rows are values of R-squared (adjusted for degrees of freedom) from capability regressions of the *NULL* form for the corresponding sub-samples of firms. The adjectives descriptive of the strength of the relationship that appear below these values are -- as before -- an attempt to make their meaning more transparent. They indicate where each value falls among the quintiles of the distribution of all the R-squared values (except those in the first column) reported in the table; there was no strong reason to adjust this quintile breakdown. 'HIGH' is applied to values in the highest quintile; 'high,' the next highest; and so on in the order 'AVERAGE,' 'low,' 'LOW.'

The exclamation and question marks that appear below some of these words indicate the significance of the characteristic's influence on the functional relationship; significance is judged using F-statistics computed without controlling for other attributes.34/ Exclamation marks denote significant at the 0.01 level; questions marks, not significant at the 0.05 level. The absence of any marks indicates significant at the 0.05 level. The single question marks appearing under medium and small for productive capability denote lack of significance individually but not taken together. In turn, the three letter acronyms, if any, that appear on the bottom line of a cell indicate independent capabilities that are excluded from the regression because of their being associated with a negative coefficient. Major change capability is excluded from all of the regressions for production capability; its absence from these regressions is not similarly noted.

The most important findings to be gleaned from this table come from comparing coupled pairs of Crln and Scor measures. The discussion here focuses on production capability. A strong functional relationship (HIGH or high Crln) coupled with a GOOD (or good) capability Scor implies that the majority of firms having the characteristic indicated have adequate or better than adequate technological strategies, at least with respect to the dependent capability involved. Medium-size firms provide an example. In turn, a strong functional relationship coupled with a POOR (or poor) capability indicates that the majority of firms having the characteristic lack effective technological strategies. Their capability is weak because they have failed to manage their technological development properly; they have failed to accumulate the requisite underlying capabilities. Here Thai firms provide an example. A weak functional relationship (low or LOW Crln) is by itself indicative of poor technological strategies among many firms having the characteristic. Examples are discussed below.

The characteristic of being foreign owned is associated with good production capability in the presence of a LOW functional relationship between it and its underpinnings. Since the capabilities in question are Thai capabilities, this result reflects mixed performance by multinational corporations in transferring technology to Thai nationals. Indeed, foreign ownership is associated with MIXED minor and major change capability as well as MIXED investment capability and technological resources. Taken together these results at least suggest one of two things: either that Thailand is not exploiting the full potential of direct foreign investment for its technological development; or that direct foreign investment is not a particularly powerful vehicle of technological development.

BoI promotion is also associated with good production capability coupled with a LOW functional relationship. A possible interpretation is that BoI promoted firms do not take sufficient advantage of the preferential right that they enjoy to import technical assistance. That is, they use imported technical assistance to improve their production performance in the short run without taking full advantage of the opportunities for assimilation that are afforded when making use of foreign technical assistance. This result suggests that BoI promotional incentives may give firms too little incentive to utilize technology transfers effectively.

Small size is associated with POOR production capability in the presence of a LOW functional relationship. Here the implication is that many small firms have some of the requisite technological underpinnings, which they fail to capitalize upon owing to ineffective management of technology. Looking across size categories, one sees that production capabilities are positively associated with size, which is consistent with expectation that technological ability is an important determinant of a firm's relative growth rate. However, the association of a low functional relationship with large size is a contrary indication insofar as it implies poor technological strategies on the part of large firms. Here it is pertinent to note that many of the large firms began their lives as large firms.

A particularly salient finding concerns the AVERAGE production capability that is associated with being an exporter and the AVERAGE functional relationship between production capability and its underpinnings among export firms. Both results strongly suggest that Thailand's industrial sector is not in the same league with Korea's, Taiwan's, and Singapore's at comparable points in their industrial development. Sticking to Korea, whose technological development is relatively well researched: There can be little question that a similar study conducted in the late 1960s or early 1970s in Korea would have found clear evidence both that Korea's export firms had the 'BEST' production capability and that they had clear, well formulated technological strategies. Moreover, Korea's export firms were its leading firms in the sense of leading the country's technological development within industry. It appears from the evidence here presented that the same statements can not be made about Thailand's export firms.

It can be inferred that Thailand's industrial exporters are relatively ill-equipped to seize opportunities in areas of potential dynamic comparative advantage. The inference is not inconsistent with the obvious fact that Thai industry is very well able to exploit its static comparative advantage. This is because the latter does not lie in technologically intensive activities. Indeed, the low technological intensity of export activities is clearly reflected in the POOR change capabilities and technological resources that are associated with being an exporter. One is led to suspect that Thailand's current industrial success is principally due to favorable short-to-medium term trends in world markets and in the factors determining the location of direct overseas investment; it is seemingly not due to well conceived technological strategies that form one of the requisites for self-sustaining industrial development.

This suspicion is supported by the overall pattern of the coupled Scor and Crln values in Table 12. Among thirty possible cases involving production and change capabilities, one finds just three in which GOOD or good capability is combined with a HIGH or high functional relationship, and only one of these involves production capability. There are ten cases in which GOOD or good capability is found together with a low or LOW functional relationship; seven where poor or POOR capability is coupled with a HIGH or high relationship; and, one in which poor or POOR capability coexists with a low or LOW relationship.35/ Thus most firms, however characterized, seemingly have technological strategies that are deficient in one respect or another. They apparently have not recognized the potential importance of technological development to their future success. At the very least, they can be inferred to have paid little systematic attention to managing their technological development. One can surmise that they have generally undertaken technological efforts on the occasion of their inception and thereafter only in response to externally induced crises of one kind or another. In short: the majority of firms in the sample appear to have technological strategies that can be characterized as being passive or reactive rather than active or aggressive.

Anecdotal evidence compiled during the course of the research strongly points to the same conclusions. Nonetheless, it is necessary to state several caveats about the validity of coupling Scor and Crln values as is done here.36/ The first caveat: To the degree that the capability scores reflect the sophistication of the technology in use rather than the capability with which it is used, the R-squared values can not be interpreted -- at least not in the direct fashion that they have been interpreted above -- simply in terms of the presence or absence of an effective technological strategy. The second caveat: The Scor values for particular characteristics are controlled for differences among firms with respect to attributes other than that to which the characteristic belongs. The Crln values are not similarly controlled. Thus there is some unknown degree of sampling bias in the Crln values. The third caveat: Scor and Crln values computed from similar regressions among individual capabilities may have a quite different pattern than do the values shown in the table. However, this caveat is important only insofar as one considers the aggregate capabilities to be of derivative or secondary analytical significance.

4 Reflections

Microscopic research on technological capability is undeniably expensive in terms of time as well as resources. This makes it of arguably questionable relevance when what is wanted is a reasonably comprehensive overview of past and present technological development. The macroscopic approach reported here is far less expensive. Moreover, the discussion in the previous section indicates that one can find out a great deal of relevance by analyzing capability scores; at least, that is what we think. Of course, macroscopic analysis, even if conducted flawlessly, is relatively crude. This means that findings drawn from it should be taken as hypotheses which need to be subjected to further scrutiny (based on other information and methods of analysis) before being accepted as valid. Nonetheless, the findings can be of great value insofar as they provide a reasonably comprehensive diagnosis and thereby serve to pinpoint areas where policy effort might most usefully focus.

In this paper we have tried to provide a reasonably complete indication of what can be discovered using a macroscopic approach based on capability scoring. We consider it important also to provide some indication of what can not be found out using this approach. One shortcoming is especially unlikely to be immediately apparent from the discussion. Macroscopic scoring affords little, if any, insight into the nature of the technological environment in which individual firms operate or the dynamics of their interactions with other firms and public agencies of various relevant kinds. Thus externalities of all kinds are effectively outside of its purview. For this reason, macroscopic scoring was supplemented with other modes of investigation in the overall research effort from which this paper is drawn. Other limitations may be apparent from the discussion, but it is nonetheless worthwhile to summarize the more serious ones.

The discovery of associations between capabilities and attributes of potential consequence helps to explain the observed scores, but it does so only to the degree that one can establish definite links between the associations and the firms' underlying technological behavior. To ascertain and verify these connections requires a microscopic approach, one centered explicitly on analyzing firm behavior in different circumstances. In turn, the assessment of associations among capabilities to enable inferences about technological strategies gives one some understanding about an important aspect of behavior. But it leaves many important questions unanswered; it alone cannot provide any insight into ways of stimulating improved management of technological development at the firm level.

In short, the analysis of macroscopic scores cannot by itself lead to detailed policy recommendations. A snapshot at a point in time cannot, by its very nature, demonstrate anything about behavior over time. Another analogy is even more revealing: Giving capability scores to firms is like giving examinations to students. The activity may disclose a great deal about study habits and levels of competence among those scored, but it cannot reveal very much of immediate and real operational relevance about the reasons why some individuals or firms score highly and others score poorly.

It is well established that there are tradeoffs in policy research between systematic analysis within a comprehensive scope on one side and the ability to identify and justify meaningful policy prescriptions on the other. The macroscopic scoring approach represents just one way of resolving these tradeoffs. Other approaches that are somewhat less comprehensive but considerably more conducive to the immediate articulation of detailed policy alternatives can be contemplated. The appendix sketches one such approach, which has not been tried in practice. We are unaware of any other relatively comprehensive approaches that have been put to the test in policy research. Clearly, much additional research is required to develop and test alternative approaches to focusing S & T planning on the development of technological capability. Only after the accumulation of some research applying alternatives will it be possible to come to any clear conclusion about the overall merits of the approach that has been demonstrated here.

Appendix: A Microscopic Approach to Policy Research

This annex sketches a microscopic approach to capability-focused policy research for S & T planning. It is offered here, as an alternative to the macroscopic scoring approach, in order to stimulate thinking and discussion.

Various ways of evaluating existing capabilities can be contemplated. Some, like macroscopic scoring, focus in the large on evaluating a firm's overall technological competence in various activities. Others, like that sketched here, focus in the small on specific episodes in a firm's use, or failure to make effective use, of technology. Comprehensive evaluation is lost by focusing on the small, but the ability to marry capability evaluation with policy analysis is gained. The approach consists of using in-depth case studies within individual firms to analyze technology utilization and (actual or potential) policy impact simultaneously. The case studies would focus on salient micro technological events in the evolution (or lack thereof) of the firms' capabilities.

The specifics of the approach are suggested by the following considerations: Historical experience is the natural laboratory for research on how government policy affects market-mediated technological development. Analysis of the behavior of firms operating under current and past policies provides necessary insights into the effects of particular policies on the choice of technology as well as on the extent and direction of technological change. But, given the way that this type of research is conventionally designed and accomplished, it can not be expected to yield sufficient information about technological changes that should have taken place but did not, or about the indigenous capabilities that were warranted to accomplish these changes but were not developed. Of course, research on the past could be designed to uncover failures of these kinds. But this could not be accomplished without using scarce technical expertise that is better employed working more directly on current and future technological development. What seems to be needed is an approach that would capitalize on the lessons of past experience while focusing on what was needed for the future.

The distinguishing feature of such an approach would be its focal concern with 'key' capabilities; that is, with capabilities that were absent in particular firms but that were clearly warranted either in the sense that they should have been developed in the past or should be developed in the present or very near term future. The domain of the search for these capabilities could be as broad as the three technological areas examined using the macroscopic scoring approach. Key capabilities would be identified through a systematic process involving a number of distinct elements:

- analysis of the underpinnings of the country's dynamic comparative advantage in tradeables, to insure the economic appropriateness of the production activities involved;

- search among the technologies available globally that could fruitfully be applied, to arrive at a small set of the most promising ones;

- economic and technical evaluation of potentially rewarding technologies in specific industrial areas;

- determination of alternative means of acquiring the selected technologies through using different mixes of local and foreign technological capabilities;

- economic and technical assessment of these alternatives, to identify the key capabilities and to establish an appropriate sequence for their development; and,

- identification of the policy changes (if any) needed for their development.

These elements, like the others involved in the research, would be undertaken in successive iterations of decreasing breadth and increasing depth. Thus, as the range of prospective choices became narrower, the information requirements would become increasingly more detailed and the analysis increasingly more refined.

The sought for capabilities would constitute only a very small sampling of those needing development in the present and near-term future; there would be no pretense of comprehensive identification or even of obtaining a somehow objectively representative sample. Furthermore, the elements enumerated above would be taken as being indicative of the factors to be considered with as much care as time permitted; there would be no pretense of rigorous application to derive conclusive evaluations. Stated simply, what would be sought is a sample that could reasonably be considered as having been drawn from the country's present and near future technological needs rather one drawn from its past development. However revolutionary the idea of drawing a sample from the future may be, one cannot easily deny its potential relevance, particularly where scarce technological talent (scientists and engineers) is to be actively involved in the research.

The identification of key technological capabilities cannot be accomplished without intimate knowledge of existing capabilities. Thus the approach would involve an examination of existing capabilities. Likewise, the determination of necessary policy changes can not be accomplished without an understanding of the dynamics of market-mediated technological development, or of decision-making and implementation processes in public agencies active in these areas. Thus the approach would also include an investigation of the factors conditioning past performance. In this respect it would contain a component of the conventional analysis of technologically-oriented past behavior. But, unlike much conventional analysis, the approach could be expected -- because of its unique sampling frame -- to uncover capabilities that should have been developed in the past, but were not, and to yield important insights into the reasons why they were not.

The research would to be divided into three stages, with a division of labor between economists and technologists that would exploit the comparative advantages of each specialization. This is shown in Table 13 which gives a summary statement of the approach. Close collaboration is called for in the first and third stages (top-left and bottom-right cells respectively) which would respectively focus on the survey of existing conditions and the final determination of policy needs. Mutual consultation rather than close collaboration is in order in the second stage, where the technologists would concentrate on developing the sample of key capabilities (bottom-left cell); the economists, on gaining the necessary understanding of past technological behavior (top-right cell).

[Table 13 about here.]

The approach sketched here entails many compromises between breadth and depth of analysis. These compromises are a matter of necessity in any exercise to identify development priorities across a reasonably wide set of possibilities. Thus the identification of key capabilities could not be expected to do more than determine choices deserving of conclusive evaluation by agents responsible for their implementation. In turn, the economic analysis of market-mediated technological development could be expected to be somewhat impressionistic and to be based largely on "targets of opportunity" uncovered in the first stage of the research. In the second stage, small samples involving case studies of the technological histories of particular firms and agencies would be the norm.

Consistent with the comprehensive scope of S & T planning, the research could be designed to touch on many if not most of the generic issues related to government policy in the country's technological cum industrial development. Insofar as it succeeded in this respect, it would be but the first step in an evolving program of policy research. It could have an important function in this regard, which would be to provide the broad-gauged empirical knowledge required to design a program of more narrowly targeted research for the future.

In the discussion here the term 'approach' has been used in place of 'framework' because a central element is missing from the design. (The use of 'approach' with respect to macroscopic scoring is analogously motivated.) There is no explicit, predetermined means for systematically incorporating the findings from microscopic research to identify key capabilities and to understand past behavior related to them into the kind of comprehensive yet reasonably detailed policy synthesis that is wanted in S & T planning. The absence is simply explained. There is no recipe that can easily be followed to develop a well-reasoned and clearly-structured statement of significant central tendencies from largely anecdotal evidence about technological behavior. Nor is there 'is any simply stated formula for how to go from the identification of key capabilities and an understanding of central behavioral tendencies to a statement of the appropriate policies to insure the development of these capabilities, let alone to generalize on this basis across the entire domain of S & T policy.

It follows that the adoption of this approach would involve a gamble of the kind frequently taken in innovative policy research. The gamble is that a means for bringing the pieces of the puzzle together would evolve out of the conduct of the research. The payoff would be found the ability to conduct policy analysis jointly with explicit evaluation of technological capability. It is left to the reader to judge whether the odds would favor success over failure, and to make any further comparisons between this approach and the macroscopic scoring approach that appear to be warranted.

Footnotes

1. They used a much narrower set of more precisely defined capabilities, which entails a far closer correspondence between scores and objectively measurable indicators of performance.

2. Full details regarding scoring methodology and other salient aspects, including the raw scores, are contained in the reports of the three area research teams. Their 'draft final reports' constitute the primary sources of information for the analysis described in this paper; see Petchsuwan, K. et al. (1988), ElecTech; Sutabutr, H., et al. (1988), MatTech; and, Yuthavong, Y., et al. (1988), BioTech. The completed final reports are contained in Kopr, et al., (1989). Additional details about the statistical analysis can be found in Westphal (1989).

3. Groupings of capabilities are listed and discussed in the order (here approximately) of their appearance in the notional hierarchy of functional relationships in section 2.3.

4. For one articulation of this perspective, see Dahlman, Ross-Larson, and Westphal (1988).

5. Labels for individual capabilities appearing in Table 1 are generally those used by the area teams. It will be observed that some labels are used inconsistently among the areas. See, for example, 'knowledge acquisition' and 'technology digestion,' which fall under minor change capability in BioTech and investment capability in MatTech. The original area labels are retained to enable meaningful reference to the underlying studies.

For capabilities common to all areas, Table 1 gives only the short definitions pertinent to BioTech and ElecTech. Short definitions pertinent to MatTech are implicit in the scoring scale used in that area, which is given in Table 2.

6. The use of the investment capability label here is something of misnomer relative to other usage which emphasizes different aspects of investment activity; see, for example, Westphal, Kim, and Dahlman (1985).

7. The weight given to technological self-sufficiency in the MatTech scores results in a bias with respect to the measurement of appropriate capabilities cum capacities, but not with respect to the measurement of capability cum capacity as defined by the MatTech research team.

8. Owing to differences in implicit definitions and scoring scales across areas, direct comparisons among firms are meaningful only within individual areas.

9. Absent information about each firm's choices of technology in terms of sophistication levels, it was not possible to control for this aspect in the analysis. In turn, by using estimation techniques that allow for errors in variables, it would have been possible formally to incorporate the bias into the analysis; however, this approach was not followed.

10. This difference is controlled for in the statistical analysis insofar as it includes dummy variables specific to area-industry combinations.

11. In the data, BoI promoted firms include all those that have ever received

BoI promotion in relation to the scored activity. However, in some cases, age data pertain to the firm per se rather than to the length of time that the firm has been engaged in the scored activity. This makes it problematic whether one could use the data set meaningfully to analyze age- (of the activity) specific hypotheses.

12. The names of the two general regression models used in this paper correspond to the independent variables appearing within each.

13. Equal numbers of observations in all cells is a special case of a proportional sample design -- the number of observations per characteristic for each attribute is the same across attributes.

14. To take the most extreme case: one observation per cell implies 432 observations for BIO Tech; the actual number of observations is 32.

15. To test for two-way interaction effects between attributes m and m′, equation (2) was augmented with terms of the form

$$\sum_{j_m} \sum_{j'_{m'}} (b_{j_m, j'_{m'}} \, d_{j_m i} \, d_{j'_{m'}, i}),$$

and the significance of the differences between the estimated values of $b_{j_m, j'_{m'}}$ and zero were evaluated.

16. Since the industry characteristics are composites that include industry plus area, this specification controls for differences in scoring approaches among area teams.

17. Tables 7 and 8 are drawn from detailed tables that include separate columns for all characteristics within each attribute.

18. Tables provided in Westphal (1989) permit one to employ stronger tests of significance.

19. Relatively very few of the significant estimates in the secondary regressions are not conformably-signed.

20. Within each cell, the number of cases underlying these entries is greater than the number underlying the entry on the first line, which involves comparisons against one specification; correspondingly, the S.S. and S.P. values can exceed the A.AS. value.

21. See, for example, Johnston (1972), pp. 192 ff.

22. Yuthavong (1988) gives details of how the scoring was carried out.

23. For clarification regarding any of the points made in this paragraph, see the pertinent discussion in section 1.1.

24. Capabilities are symbolized using the acronyms for aggregate capabilities that are given in Table 1.

25. The equations cannot be estimated in log-linear form using standardized scores, since these scores are not restricted to strictly positive values. They could be transformed into positive values by adding a sufficiently large constant to each, but this would introduce spurious correlations among capabilities. Raw scores can be used in log-linear regressions, but their use leads to problems when data are pooled across areas. These problems stem from

the need to control somehow for differences in scoring scales among research teams. A single set of area-specific dummy variables does not suffice to control for these differences when the scoring scales differ, as they appear to, with respect to both average and standard deviation. Moreover, it is not possible to test for real differences in the relationships across areas when differences in scoring scales can affect the parameter estimates that are associated with area-specific dummy variables.

26. As before, attribute variables must be transformed before they can be used in estimation; see the discussion in the last paragraph of section 2.1.1.

27. The designation of Thai firms remained unchanged; the two foreign characteristics under the respective ownership attributes were simply collapsed into one.

28. The only difference is that here several variables and parameters are associated with each characteristic of an attribute.

29. Use of the *OMIT* regressions in this way does not constrain the parameters that are associated with other attributes to have identical values across sub-samples. Such constraints could be introduced by using variants of the *NULL* regression specification. In one variant, for example, values of the dependent variable are taken from the corresponding *ALL* regression; they are respectively equal to the residuals plus the sum of the terms involving the given attribute.

30. This happens when negative coefficient estimates exceed their respective standard errors in absolute magnitude.

31. Similarly, the exclusion of major change capability from the regressions for productive capability makes hardly any difference in the results.

32. Because each score differential is "controlled" for differences among firms with respect to other attributes, one must add values shown in the table to determine capability measures at the firm level. With respect to this analysis, no firm is simply, for example, an export firm; it is an export firm of a particular size and ownership, either having or not having promotion, and existing within a particular industry. The values to be added include the corresponding population average and the score differentials for the corresponding characteristics (including industry, which is not shown in the table).

33. The adjustments were minor; it is also pertinent to note that the break points between "GOOD" versus "good" and "BAD" versus "bad" were very close to being one standard deviation away from the mean value.

34. Significance levels indicated in Table 12 are for characteristics and may thus differ from those given in the 'No others' row in Table 11, which are for attributes. The significance levels for characteristics are based on F-statistics computed between characteristic pairs (see the discussion in section 2.3.2).

35. The simple correlation coefficient between Scor and Crln values over the thirty pairs is -0.26. In this computation, Scor values associated with the ownership attribute are simple averages of those shown in each cell of Table 12.

36. A highly technical matter not elsewhere discussed also warrants mention. Conventional least-squares techniques were used in estimating all regressions reported in this paper. It is possible that -- owing to their nature -- the capability scores are best analyzed using techniques appropriate to qualitative (multi-) response models [for a survey of such models, see Amemiya (1981).] However, it is far from clear to us that these techniques are the only proper ones for all of the analysis. Owing to aggregation, the variables employed in most of the estimation are continuous, albeit bounded, though without values bunched at the boundaries. The only use of discrete variables is in the ALL Area regressions for individual capabilities that are discussed in section 2.1. We did not have the resources during the course of the work to resolve the issue. Nor would we have had access to the requisite computational software had we determined that the techniques were relevant. Moreover, we understand that it is not uncommon to employ least-squares techniques in initial explorations using qualitative response data.

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Table 1.A
Technological Capabilities

1. <u>PRODUCTION CAPABILITY *(acronym, Prodn)*</u>

a. <u>Individual Capabilities Included in the Aggregate Capability</u>

Common among all: Operation -- to operate current or new technology effectively (B, 7); to operate the production process efficiently (E, 7).

Specific to Elec: Quality control -- to insure yield, uniformity, and performance (9).
Inventory control -- to monitor and control inventories for continuous production at reasonable cost (10).

Specific to Mat: Competitiveness -- to compete in local and world markets (10).

b. <u>Individual Capabilities Related to (but not included in) the Aggregate Capability</u>

Specific to Bio: Management -- to manage efficient production (10).
Skills -- to carry out technical activities (9).

Specific to Mat: Management -- to manage efficiently (11).

2. <u>MAJOR CHANGE CAPABILITY *(acronym, MajCh)*</u>

a. <u>Individual Capabilities Included in the Aggregate Capability</u>

Common among all: Major product change -- to make major product changes (B, 16); to make major, significant changes in product appearance, function, and performance (E, 16).
Major process change -- to make major process changes (B, 17); to make major changes in processes that lead to significant gains in productivity (E, 17).
Invention -- to create new products (B, 19); to create completely new products (E, 18).

Specific to Bio: Diversification -- to undertake major diversification of principal activities (20).

Specific to Elec: Reverse engineering -- to acquire new product designs through reverse engineering (12).

Specific to Mat: Intermediate change -- to make changes in processes or products of an intermediate nature relative to minor versus major changes (19).

b. <u>Individual Capabilities Related to (but not included in) the Aggregate Capability</u>

There are none.

Notes appear at the end of the table.

3. <u>MINOR CHANGE CAPABILITY *(acronym, MinCh)*</u>

a. <u>Individual Capabilities Included in the Aggregate Capability</u>

Common among all: Minor product change -- to make minor product modifications (B, 12);
to make minor changes in product design or raw material use, to suit local conditions and reduce costs (E, 13).
Minor process change -- to make minor process modifications (B, 13);
to make minor changes in processes, to increase efficiency and reduce costs (E, 14).

b. <u>Individual Capabilities Related to (but not included in) the Aggregate Capability</u>

Specific to Bio: Knowledge acquisition -- to acquire relevant new knowledge, with specific reference to adapting technology (14).
Technology digestion -- to successfully apply new knowledge, with specific reference to adapting technology (15).

4. <u>INVESTMENT (or Acquisitive) CAPABILITY *(acronym, Invst)*</u>

a. <u>Individual Capabilities Included in the Aggregate Capability</u>

Common among all: Search -- to seek new technology (B, 1);
to find the required technology (E, 1).
Assessment -- to assess various technological options (B, 2);
to evaluate the merits of a technology, to make comparisons among technologies (E, 2).
Negotiation -- to obtain favorable transfer terms (B, 3);
to obtain reasonable terms for the chosen technology (E, 3).
Procurement -- to buy new technology (B, 4);
to successfully purchase the chosen technology (E, 4).
Installation and startup -- to install new technology successfully (B, 6);
to install and startup new machines, to perform tests necessary to achieve satisfactory performance (E, 6).

b. <u>Individual Capabilities Related to (but not included in) the Aggregate Capability</u>

Specific to Bio: Transfer -- to complete a successful transfer (5).

Specific to Elec: Design and layout -- to design and layout new production lines (5).

Specific to Mat: Transfer -- effectively to assimilate the technology obtained (5).
Knowledge acquisition -- to source technology effectively (12).
Technology digestion -- to master process technology in terms of both know-how and know-why (13).

Notes appear at the end of the table.

Table 1.C
Technological Capabilities

5. TECHNOLOGICAL RESOURCES *(acronym, TecRe)*

a. Individual Capabilities Included in the Aggregate Capability

Common among all: Training -- capacity for training manpower (B, 11);
quality of and investment in training programs, both in-house and external (E, 11).
R & D -- capacity for carrying out true R&D (B, 18);
capacity for conducting R, D, & E, as reflected in budget, facilities, number and quality of specialized personnel (E, 15).

b. Individual Capabilities Related to (but not included in) the Aggregate Capability

Common among all: Maintenance -- capacity for maintaining production equipment (B, 8);
capacity for keeping machinery and process in proper operating condition, and for calibrating testing and measuring instruments (E, 8).

Sources: Westphal (1989), Tables 1 and 2.

Notes: Unless context indicates otherwise, capabilities are those 'to ...'.

As is indicated in the text, technological resources denote capacities in the sense of resource endowment rather than capabilities in the sense of ability in using resources. Nonetheless, for expositional convenience, the term 'technological capabilities' is the general term that is used to refer to all scored capabilities and capacities.

For common individual capabilities: short definitions paraphrase those given in BioTech and ElecTech final reports, letters in parentheses indicate the area — B for BioTech and E for ElecTech; for MatTech, see Table 2.

For common and specific individual capabilities: numbers in parentheses indicate the order in which individual capabilities are listed in the draft final reports on each technological area; capabilities are in some cases titled differently in these reports.

Individual capabilities absent for one technological area that are explicitly identified for some other area(s) were in most cases implicitly considered — with respect to the former area — as falling within some explicitly identified capability.

Table 2.A
Scoring Scales

BioTechnology Area

Capability	Score	Considerations
All Capabilities	5:	Equals that of firms on world FRONTIER
	4:	Equals AVERAGE found in industrial countries
	3:	BELOW AVERAGE in industrial countries; GREATER than in most local firms
	2:	WELL BELOW AVERAGE in industrial countries; EQUALS local average
	1:	BELOW local average or NO CAPABILITY

Electronics Technology Area

Capability	Score	Considerations
All Capabilities	5:	Comparable to leading firms in industrial countries
	4:	Adequate for export except to most competitive markets
	3:	Acceptable for expansion within local markets
	2:	Acceptable for low end of the local market
	1:	Unacceptable quality due to deficiency in design and production
	0:	Absence of capability

Materials Technology Area

Capability	Score	Considerations
Operation (7)	5:	Efficient operation with: good plant layout and environment; good inventory and quality control; adequate safety programs; etcetera
	4:	Inferior to 5 in plant environment or several other aspects
	3:	Inferior to 4 in plant layout or several other aspects
	2:	Inferior to 3 in safety programs or several other aspects
	1:	Poor in all respects
Competitive-ness (10)	-	OVERALL COMPETITIVENESS OF PRODUCTION
	5:	Internationally competitive
	4:	Superior to most local firms
	3:	Strong competitor in local market
	2:	Weak competitor in local market
	1:	Unable to produce with acceptable quality
Management (11)	5:	Modern, by international standards
	4:	Somewhat inferior to 5, but well organized, with clear functional specialization
	3:	Less well organized
	2:	No clear functional specialization
	1:	Poorly organized individual or family management

Notes appear at the end of the table.

Table 2.B

Scoring Scales *(MatTech continued)*

Capability	Score:	Considerations		
Major and Minor Change Capabilities	-	REQUIRES		
	5:	No external assistance		
	4:	Some local assistance		
	3:	Some foreign assistance		
	2:	Extensive foreign assistance		
	1:	Purchase of foreign technology		
	0:	No such changes made		
		Individual capabilities to which the scale above applies:		
		Major Change Capabilities		
		Major Product Change (17)		
		Major Process Change (18)		
		Invention (20)		
		Intermediate Change (19)		
		Minor Change Capabilities		
		Minor Product Change (14)		
		Minor Process Change (15)		
Search (1)	-	SYSTEMATIC	SOURCES	PIONEER STATUS
	5:	Yes	Several	n.a.
	4:	No	"	Local pioneer
	3:	"	"	Not pioneer
	2:	"	One or few	"
	1:	"	Copy local firms	"
		Note: Possible sources include technical literature, seminars, exhibitions, professional associations, etc.		
Assessment (2)	-	ASSESSMENT	EVALUATE	STAFF QUALIFICATIONS
	5:	Complete	All components	Fully qualified
	4:	"	Some or all components	Partly qualified
	3:	"	Overall system	"
	2:	Rough	"	"
	1:	No technical evaluation		
Negotiation (3)	-	SOURCES	LOCALIZATION OPTION	
	5:	Several	Yes	
	4:	"	No	
	3:	Only a few	"	
	2:	One	"	
	1:	Negotiation on basis of very little information		
Procurement (4)	-	SOURCES OF COMPONENTS		LOCAL FABRICATION TO OWN SPECIFICATIONS
		LOCAL	FOREIGN	
	5:	Several	n.a.	Yes, for some elements
	4:	"	Several	n.a.
	3:	"	One	"
	2:	None	One	No
	1:	Turnkey project		

Notes appear at the end of the table.

Table 2.C

Scoring Scales *(MatTech continued)*

Capability	Score	Considerations: REQUIRES
Installation and Startup (6)	5	No external assistance
	4	Some local assistance
	3	Some foreign assistance
	2	Largely foreign expertise
	1	Turnkey project

Capability	Score	UNDERSTANDING	OWN R&D INVOLVED	RELIANCE ON FOREIGNERS
Transfer (5)	5	In-depth	Yes	n.a.
	4	"	No	"
	3	Weak	"	"
	2	"	"	Extensive, for long period
	1	Very poor	"	Continued, for routine problems

Capability	Score	SYSTEMATIC	SOURCES
Knowledge Aquisition (12)	5	Yes	Many, including overseas travel
	4	"	Several
	3	No	Few
	2	"	Customers and/or suppliers only
	1	Copies other local firms	

Capability	Score	PROCESS KNOWLEDGE	R&D UNIT
Technology Digestion (13)	5	Complete, from in-depth study	Yes
	4	Incomplete	"
	3	"	No
	2	Personnel lack qualifications for in-depth understanding	
	1	No analysis of the technology in use	

Capability	Score	COVERAGE	PROGRAMS: OVERSEAS	PROGRAMS: IN-HOUSE
Training (9)	5	Extensive, systematic; using local sources	Yes	Yes
	4	"	Limited	"
	3	"	"	No
	2	Limited to only some areas	"	"
	1	Very limited training		
	0	No training program		

Capability	Score	Considerations
R and D (16)	5	Distinctly funded R&D activities within separate R&D unit having adequate facilities
	4	Inferior to 5
	3	Inferior to 4
	2	Some R&D activities within technical department
	1	Technical personnel lack adequate qualifications
	0	Firm has no R&D activities

Notes appear at the end of the table.

Table 2.D
Scoring Scales *(MatTech continued)*

Capability	Score	Considerations
Maintenance (8)	5	Planned maintenance, employing appropriate method(s), using special equipment to monitor machinery performance
"	4	Inferior to 5 in not using special equipment or several other aspects
	3	Inferior to 4 in method used or several other aspects
	2	Maintenance improperly planned or largely unplanned
	1	Maintenance only upon machine failure

Source: Westphal (1989), Tables 3 and 4.
Notes: " denotes 'ditto' or 'as immediately above'.
n.a. denotes not applicable; that is, not an explicit consideration.
For Materials Technology --
Individual capabilities appear in the same order as in Table 1.
Within each page of the table:
= = = ... demarcates different aggregate capabilities;
= - = ... separates included from related individual capabilities;
- - - ... demarcates different individual capabilities that fall within the same cluster.
Numbers in parentheses in the left column indicate the order in which individual capabilities are listed in the final report on the MatTech area; individual capabilities are in some cases titled differently in that report.

Table 3
Industries Included in the Area Samples

Area and Industry	Principal activities or products
BioTech	
Aquaculture	Large and small shrimp, 4; shrimp feed, 2; fish, 1.
Animal feed	Chicken feed, 2; duck feed, 2; fish feed, 2; pig feed, 2; fish, 1; fodder, 1; shrimp feed, 1; starch (simple & modified), 1.
Seed production	For: cabbage, 3; melon, 3; chile, 1; chinese kale, 1; tomato, 1; various other vegetables.
Dairy	Fresh milk, 2; U.H.T milk, 2; butter, 2; animal feed, 1; condensed, evaporated, and sterilized milk, 1; ice-cream, 1; yogurt, 1.
Ornamental flowers	Orchids, 4.
Organic acids	Mono sodium glutamate, 3; chili sauce, vinegar, and miscellaneous seasonings, 1.
Alcohol	Alcohol, 2; liquor, 2; beer, 1; wine, 1.
Health products	Antibiotics, 2; cosmetics, etc., 2: drugs, 2; chemicals, 1; diagnostic elements, 1; oils and fats, 1; vaccines: human, 1; animal, 1.
MatTech	
Metal products	Fabrication of industrial and agricultural machinery, 8; casting, 6; die making and press work, 6; machining, 3; forging, 2; engine parts, 2; heat treatment, 2.
Plastic products	Resins, 4; blow and injection moulding, 3.
Ceramic products	Refractories, 4; floor and wall tile, 3; sanitary ware, 3; compound clay, 1; insulators, 1; tableware, 1.
Rubber products	Engineering rubber, 5; latex products, 1.
ElecTech	
Consumer electronics	Color televisions, 5; radio-cassette combinations, 4; car and home stereo sets, 3; microwave ovens, 1.
Communication equipment	Radio transceivers, 2; telephones and related equipment, 1.
Computer hardware	Microcomputers, 2; Thai cards, 1; monitors, 1.
Industrial electronics	Education kits, 1; electronic parts, 1; microwave components, 1; power line stabilizers, 1; uninterrupted power supplies, 1; solar cell panels, 1.
Electronic components	Integrated circuit assembly, 3; printed circuit boards, 3; ball bearings, 1; cables, 1; condensers, 1; disk drive assemblies, 1; coils, resistors, speakers, transformers, tuners, 1.
Computer software	Various kinds of software, 3.

Source: Westphal (1989), Table 5.

Notes: Numbers indicate the number of firms producing the respective products; owing to the production of multiple products by individual firms, they do not necessarily sum to the total number of firms shown in Table 5.

Table 4

Summary of Firm Descriptor Information

Attributes and Characteristics	*	BioTech	MatTech
Size:	SIZ	Same as for MatTech.	Loosely based on registered plus paid-up capital, K, in M bhat, and labor force, L, in persons:
Large	-L		K >= 25, L >= 250
Medium	-M]		25 > K >= 5, 250 > L >= 50
Small	-S		5 > K, 50 > L
Ownership (and management):	OWN	Thai share of ownership, T, and nationality of senior manager:	Thai share of ownership, T, and nationality of senior manager:
Thai	-T]	T = 1.0	T >= 0.9
Foreign:			
- Joint venture	-J	[n.a.]	[n.a.]
Foreign sub.	-F	[n.a.]	[n.a.]
- For. (Thai)	-NT	T < 1.0 with Thai management	T < 0.9 with Thai management
For. (For.)	-NF	T < 1.0 with foreign management	T < 0.9 with foreign management
Market orient:	MKT	Export share in total sales, E:	Same as for ElecTech.
Domestic	-D]	0.0 = E	
Both (D. & E.)	-B	1.0 > E > .0	
Export	-E	E = 1.0	
BoI status:	PRO	BoI promotional status:	Same for all areas.
Promoted	-Y	has received promotion	
Not promoted	-N]	has never received promotion	

Attributes and Characteristics	*	ElecTech
Size:	SIZ	Based on labor force, L, in persons, and sales revenue, S, in M bhat:
Large	-L	L >= 300 or S >= 500
Medium	-M]	300 > L >= 100 and 500 > S >= 50
Small	-S	100 > L or 50 > S
Ownership (and management):	OWN	Thai share of ownership, T:
Thai	-T]	T >= 0.9
Foreign:		
- Joint venture	-J	0.9 > T >= 0.1
Foreign sub.	-F	0.1 > T
- For. (Thai)	-NT	[n.a.]
For. (For.)	-NF	[n.a.]
Market orient:	MKT	Export share in total sales, E:
Domestic	-D]	0.2 >= E
Both (D. & E.)	-B	0.8 > E > 0.2
Export	-E	E >= 0.8
BoI status:	PRO	Same for all areas.
Promoted	-Y	
Not promoted	-N]	

Source: Westphal (1989), Table 6.

Notes: * Acronyms.

] Denotes implicit characteristic in statistical analysis; significance levels not determined for associated parameters.

n.a. Not applicable.

M, million.

Table 5
Sample Composition by Individual Characteristics

Technological areas and industries	No. of Firms	Age: Old	Age: New	SIZ-: L	SIZ-: M	SIZ-: S	OWN-: T	OWN-: NT/J	OWN-: NF/F	MKT-: D	MKT-: B	MKT-: E	PRO-: Y	PRO-: N
BioTech	32	67	1	16	12	4	20	6	6	14	9	9	15	17
Aquaculture	4	4	1	3	1	0	1	3	0	0	2	2	4	0
Animal feed	4	42	7	2	2	0	3	0	1	2	1	1	1	3
Seed production	3	67	4	2	1	0	2	0	1	2	1	0	1	2
Dairy	3	26	15	1	1	1	2	0	1	3	0	0	2	1
Ornamental flowers	4	13	5	0	2	2	4	0	0	0	0	4	1	3
Ogranic acids	4	27	2	3	1	0	2	1	1	0	4	0	2	2
Alcohol	4	12	5	2	2	0	3	1	0	1	1	2	1	3
Health care products	6	58	9	3	2	1	3	1	2	6	0	0	3	3
MatTech	55	27	3	34	14	7	45	6	4	8	24	2	28	27
Metal products	29	27	3	18	7	4	23	4	2	5	16	1	16	13
Plastic products	7	25	6	7	0	0	7	0	0	0	1	0	3	4
Ceramic products	13	20	5	7	5	1	11	2	0	2	5	0	6	7
Rubber products	6	25	3	2	2	2	4	0	2	1	2	1	3	3
ElecTech	32	28	1	15	9	8	17	6	9	18	0	14	19	13
Consumer electronics	8	24	1	4	4	0	4	3	1	7	0	1	5	3
Communication equipment	3	20	1	1	1	1	2	0	1	2	0	1	2	1
Computer hardware	4	14	2	2	0	2	2	0	2	3	0	1	1	3
Industrial electronics	4	10	3	0	1	3	3	1	0	2	0	2	2	2
Electronic components	10	16	3	7	2	1	3	2	5	1	0	9	9	1
Computer software	3	28	3	1	1	1	3	0	0	3	0	0	0	3
POOLED SAMPLES	119	67	1	65	35	19	82	18	19	40	33	25	62	57

Source: Westphal (1989), Table 7.

Notes: Age is in years; entries under Old give age of oldest firm in the sample; New, the youngest firm.

In the SIZ, OWN, MKT, and PRO columns: acronyms given as column headings are defined in Table 4; cell entries indicate number of firms having the stated characteristic.

In the OWN columns: NT and NF apply to BioTech and MatTech; J and F, to ElecTech.

A number of MatTech firms were not classified by the MKT attribute: in metal products, 7 firms; plastic products, 6; ceramic products, 6; rubber products, 2; overall, 21.

Table 6
Selected Sample Statistics

-*-*-*- RAW SCORES, INDIVIDUAL CAPABILITIES -*-*-*-

	Average	Standard Deviation	Coefficient of Variation
BioTech	3.13	1.25	0.40
ElecTech	2.40	1.42	0.59
MatTech	3.04	1.47	0.48

-*-*- PROPORTIONAL CONTRIBUTION TO TOTAL VARIANCE -*-*-
-*-*- ALL INDIVIDUAL CAPABILITIES TOGETHER -*-*-

	Firm Effects	Capability Effects	Interaction Effects
BioTech	0.33	0.26	0.41
ElecTech	0.21	0.43	0.37
MatTech	0.20	0.37	0.43

-*- CORRELATIONS AMONG INDIVIDUAL CAPABILITIES -*-

	Average	Standard Deviation	Maximum	Minimum
BioTech	0.44	0.17	-0.07	0.93
ElecTech	0.36	0.29	-0.41	0.87
MatTech	0.29	0.23	-0.19	0.80

-*-*- PROPORTION OF VARIANCE LOST IN AGGREGATION -*-*-

	Prodn	MajCh	MinCh	Invst	TecRe	All
BioTech	0.59	0.50*	0.57	0.47	0.55	0.47
ElecTech	0.11*	0.77*	0.30*	0.25	0.67	0.39
MatTech	0.42	0.70*	0.25*	0.69	0.51	0.44

-*-*- PROPORTIONAL CONTRIBUTION TO TOTAL VARIANCE -*-*-
-*-*- ALL AGGREGATE CAPABILITIES TOGETHER -*-*-

	Firm Effects	Capability Effects	Interaction Effects
BioTech	0.40	0.34	0.26
ElecTech	0.35	0.33	0.33
MatTech	0.32	0.42	0.27
Pool	0.35	0.34	0.31

-*-*- CORRELATIONS AMONG AGGREGATE CAPABILITIES -*-*-

	Average	Standard Deviation	Maximum	Minimum
BioTech	0.54	0.08	0.42	0.70
ElecTech	0.41	0.30	-0.13	0.77
MatTech	0.42	0.19	0.17	0.78
Pool	0.43	0.10	0.19	0.56

Sources: Westphal (1989), Tables 9 & 19, and later computations.

Notes: Totals may not reconcile due to round-off error.

Contributions to total variance: firm effects -- variance of average scores across firms; capability effects -- variance of average scores across capabilities; interaction effects -- variance of residuals, raw scores minus corresponding firm and capability averages.

Variance lost in aggregation: variance of residuals, scores for included and related individual capabilities minus scores for corresponding aggregate capability(ties); capability acronyms in column headings are defined in Table 1.

* Variance of aggregate capabilities relative to variance of included and related individual capabilities equals one minus proportion of variance lost in aggregation, this because all individual capabilities are 'included' (none are 'related'). In all other cases but one, the relative variance of the aggregate capability across firms exceeds one minus the proportion lost.

Table 7
Attribute Regressions for Individual Capabilities: Summary Statistics

Memo Items		Industry Attributes	Other Attributes: SIZ	OWN	MKT	PRO	All	Age Variable
Production Capability	A.AS.	80	93	78	75	67	79	89
	S.S.	27	83	29	25	25	45	33
	S.P.	8	50	8	5	8	23	0
Major Change Capability	A.AS.	78	72	67	75	67	72	92
	S.S.	40	33	37	36	33	35	80
	S.P.	27	3	33	16	20	16	27
Minor Change Capability	A.AS.	73	88	63	82	75	78	88
	S.S.	31	50	32	26	18	35	73
	S.P.	17	0	9	5	9	4	9
Investment Capability	A.AS.	85	87	82	70	75	78	75
	S.S.	43	72	41	18	13	42	65
	S.P.	23	48	17	8	4	23	13
Technological Resources	A.AS.	76	93	78	75	56	80	89
	S.S.	32	25	25	15	25	25	17
	S.P.	15	17	4	5	8	13	0
Aggregation over All Capabilities	A.AS.	80	86	75	74	69	78	84
	S.S.	36	55	34	24	22	37	56
	S.P.	19	27	16	8	10	17	11

Source: Westphal (1989), Table 16.

Notes: Acronyms given as column headings under Other Attributes are defined in Table 4.

A.AS. = Coefficients of regressions for individual capabilities included in and related to the corresponding aggregate capability that have the same algebraic sign as that in the ALL Area regression for the aggregate capability, percent of maximum number possible.

S.S. = Coefficients -- of ALL Area regression for the corresponding aggregate capability, and of regressions for (included and related) individual capabilities that have the same algebraic sign as that in the ALL Area regression -- that exceed their respective standard errors, percent of maximum number possible.

S.S. = Coefficients -- of ALL Area regression for the corresponding aggregate capability, and of regressions for (included and related) individual capabilities that have the same algebraic sign as that in the ALL Area regression -- that significantly differ from zero at the 0.10 level, percent of maximum possible.

Table 6

Attribute Regressions for Aggregate Capabilities: Summary Statistics

Memo Items		Industry Attributes	Other Attributes: SIZ	OWN	MKT	PRO	All	Age Variable
Production Capability	A.AS.	86	83	94	63	67	79	67
	S.S.	31	93	44	42	71	61	75
	S.P.	9	79	25	8	71	43	0
	F-stat.	1.32	8.46$$	3.24$	0.19	5.40$	10.88$$	--
Major Change Capability	A.AS.	86	72	78	81	67	76	100
	S.S.	47	29	38	67	43	43	100
	S.P.	36	0	31	33	0	18	50
	F-stat.	3.80$$	0.81	1.85	2.83	1.19	1.65	--
Minor Change Capability	A.AS.	83	83	78	88	67	81	67
	S.S.	49	79	50	67	29	59	75
	S.P.	33	36	19	33	14	27	0
	F-stat.	3.99$$	5.83$$	1.28	2.67	0.33	3.32$$	--
Investment Capability	A.AS.	92	83	94	69	67	81	67
	S.S.	47	79	31	25	14	41	25
	S.P.	27	43	13	17	14	22	0
	F-stat.	3.23$$	4.39$	2.07	0.13	0.55	2.00$	--
Technological Resources	A.AS.	92	100	94	75	83	90	33
	S.S.	40	57	31	42	57	45	0
	S.P.	16	36	0	17	43	20	0
	F-stat.	1.77$	2.77	2.83$	1.82	7.50$$	4.89$$	--
Aggregation over All Capabilities	A.AS.	88	84	88	75	70	81	67
	S.S.	43	67	39	48	43	50	55
	S.P.	24	39	18	22	29	26	10

Source: Westphal (1989), Tables 12.2 and 14.2, and later computations.

Notes: Acronyms given as column headings under Other Attributes are defined in Table 4.

A.AS. = Coefficients of ALL and ONE Area regressions that have the same algrebraic sign as that in the ALL Pool regression, percent of maximum number possible.

S.S. = Coefficients -- of ALL Pool regression, and of ALL & ONE Area regressions that have the same algebraic sign as that in the ALL Pool regression -- that exceed their respective standard errors, percent of maximum number possible.

S.P. = Coefficients -- of ALL Pool regression, and of ALL & ONE Area regressions that have the same algebraic sign as that in the ALL Pool regression -- that significantly differ from zero at the 0.10 level, percent of maximum number possible.

F-stat. = F-statistic for the null hypothesis of no association between capability scores and the corresponding attribute; unrestricted model is the ALL Pool regression; restricted model, OMIT regression for the corresponding attribute. $$ and $ respectively indicate that the null hypothesis can be rejected at the 0.01 and 0.05 significance levels.

Table 9
Sophistication of Technologies in BioTech Firms

Technology / Industry	AQC	FED	SED	DRY	FLO	ACD	ALC	PHR	All
Engineering and related									
Chemical engineering		3.00		3.50		3.25	2.75	3.60	3.24
Chemical technology								3.00	3.00
Chemical analysis		2.25				3.25	2.00	2.50	2.50
Control & measurement	2.75	3.00	3.00	3.00		3.25	2.50	3.50	3.03
Controlled environment	2.50		3.50	3.00	3.50	3.67		2.80	3.13
Computer-aided production		5.00						3.50	4.00
Dehydration technology		2.50	2.00			3.67		3.33	2.88
Reactor technology						4.25	2.50	3.50	3.40
Industrial engineering		3.50		2.67		3.00	2.75	3.60	3.15
Average score	2.63	3.05	2.83	3.07	3.50	3.46	2.50	3.28	3.08
Biological technologies									
Biochemical						3.33	3.00	3.00	3.20
Biochemical analysis			3.00	3.00		3.67		3.00	3.12
Enzyme						3.33	3.00	3.00	3.20
rDNA (genetic engineering)									
Hybridoma / fusion									
Microbial	2.00			2.50		3.00	2.00	3.00	2.57
Plant tissue culture					4.00				4.00
Plant breeding			5.00		3.25			4.00	4.11
Average score	2.00		4.00	2.75	3.63	3.31	2.33	3.07	3.15
Intermediate technologies									
Fermentation				4.00		4.25	2.50	3.50	3.45
Biochemical engineering						3.00		3.00	3.00
Pollution control #		2.33		2.25		3.50	2.83	2.00	2.66
Average score		2.33		2.60		3.78	2.70	3.00	2.94
Others									
Consumer testing				2.67	3.00			3.00	2.90
Clinical field testing		3.25	4.00					3.33	3.50
Average score		3.25	4.00	2.67	3.00			3.22	3.25
Overall average score	2.45	2.94	3.42	2.87	3.44	3.48	2.53	3.21	3.09
Standard deviation	0.50	0.93	1.19	1.04	0.61	0.87	0.55	0.86	0.93

Source: Westphal (1989), Table 17.

Notes: The column order in which industries appear is the same as the row order in which they appear in Table 3. Blank cells denote technologies not in use by firms sampled; averages and standard deviations are with respect to technologies in use. Row and column averages correspond to weighted averages of cell values, with weights being the number of observations within each cell.

Table 10

Capability Scores Regressed against Sophistication Scores

Capability	Capability Score	Constant	Slope	R-squared
Production	ALL Pool	1.40	-0.28	0.18
		(0.80)	(0.27)	
	ALL BioTech	5.50	-0.55	0.27
		(1.21)	(0.40)	
Major Change	ALL Pool	1.39	-0.76	0.20
		(2.09)	(0.69)	
	ALL BioTech	5.16	-1.02*	0.32
		(2.02)	0.67	
Minor Change	ALL Pool	0.42	-0.14	0.01
		(2.04)	(0.68)	
	ALL BioTech	4.19	-0.26	0.03
		(1.90)	(0.63)	
Investment	ALL Pool	2.41	-0.77*	0.38
		(1.31)	(0.43)	
	ALL BioTech	5.87	-0.83	0.26
		(1.87)	(0.62)	
Technological Resources	ALL Pool	-1.72	0.43	0.08
		(1.96)	(0.65)	
	ALL BioTech	-0.77	0.97	0.25
		(2.29)	(0.76)	

Source: Westphal (1989), Table 18.

Notes: Capability scores are estimates of the constant terms in attribute regression specifications identified under the heading, 'Capability Score;' sophistication scores are the 'Overall average scores' given at the bottom of Table 12.

For each regression: the eight BioTech industries comprise the sample; the first line gives the coefficient estimates (along with R-squared); the second line, the corresponding standard errors.

* indicates value is significantly different from zero (t-test) at the 0.10 level.

Table 11
Capability Regressions: Selected Results

-*-*- F-STATISTICS FOR ATTRIBUTE SIGNIFICANCE -*-*-

Dependent Capability	Attributes Controlled For	Area Atrb	Other Attributes SIZ	OWN	MKT	PRO	All
Production	All others	1.39	1.66	1.10	1.30	1.51	2.53$$
	All non-area	—	2.22$	1.00	2.16$	0.92	3.72$$
	No others	3.81$$	5.25$$	7.81$$	5.24$$	4.64$$	—
Major Change	All others	2.50$	2.28$	0.95	0.90	1.91	1.75$
	All non-area	—	2.79$$	0.41	1.51	2.29	1.64$
	No others	2.43$	1.74	0.92	1.49	1.41	—
Minor Change	All others	2.78$	0.32	0.49	4.95$$	0.61	1.86$
	All non-area	—	0.38	0.80	7.34$$	0.61	2.87$$
	No others	5.91$$	0.60	0.91	10.32$$	0.46	—

-*- PARAMETER ESTIMATES FOR NULL REGRESSIONS USING ALL OBSERVATIONS -*-

Dependent Capability	Constant	Independent Capabilities MajCh	MinCh	Invst	TecRe	R-sq'd	Signif-cance
Production	0.64$$	-0.14#	0.10#	0.12	0.37$$	0.35	0.01
	(0.11)	(0.10)	(0.07)	(0.11)	(0.07)		
	0.76$$	—	0.07#	0.08	0.35$$	0.34	0.01
	(0.06)		(0.06)	(0.11)	(0.07)		
Major Change	-0.85$$	—	0.16$$	0.23$	0.13$	0.30	0.01
	(0.06)		(0.06)	(0.10)	(0.06)		
Minor Change	0.21$	—	—	0.65$$	0.29$$	0.34	0.01
	(0.09)			(0.14)	(0.09)		

Source: Computations done for this paper.

Notes: F-statistics:

Acronyms given as column headings under Other Attributes are defined in Table 4.

$$ and $ respectively indicate value significantly different from zero at the 0.01 and 0.05 levels.

Parameter estimates:

Capability acronyms in column headings are defined in Table 1.

For each regression, the first line gives the coefficient estimates (along with R-squared and significance level); the second line, the corresponding standard errors.

$$, $, *, and # respectively indicate value significantly different from zero (t-test) at the 0.01, 0.05, 0.10, and 0.25 levels.

Table 12.A
Technological Capabilities and Functional Correlations

	. a	..ALL.. .Firms.	Large	Medium	Small	Thai	Foreign
			Size			Ownership	
	S					-.34+	.17+
	c	.58$$	.26$$	.06+	-.32$$	-.23+	.11+
	o		GOOD#	good	POOR#	POOR#	good
Production	r		!!		!!	!!	!!
Capability	C	.32$$	.25$$	.42$$	-.08_	.37$$	.12$
	r		low	high	LOW*	high	LOW#
	l		!!	?	?	!!	!!
	n		min				min inv
	S					-.11+	.06+
	c	-.08$$	-.09_	.09+	.0-_	-.16+	.08+
	o		poor	good	AVERAGE	poor	MIXED
Major Change	r		??			??	
Capability	C	.28$$	.33$$	.27$$	.48$$	.30$$	.26$$
	r		AVERAGE	low	HIGH#	AVERAGE	low
	l		??	??	??	??	??
	n				inv		
	S					-.11+	.05+
	c	-.04_	.39$$	-.0-+	-.39$	-.07+	.03+
	o		GOOD*	AVERAGE	POOR*	poor	MIXED
Minor Change	r		!!		!!	??	
Capability	C	.33$$	.23$$	.35$$	.41$$	.39$$	.22$$
	r		low	AVERAGE	high	high	low
	l		??	??	??	??	??
	n						
	S					.30+	-.15+
Investment	c	.12_	.18$	.12+	-.29$$	-.03+	.02+
Capability	o		GOOD	good	POOR#	MIXED	MIXED
	r		!!	!!	!!		
	S					-.10+	.05+
Technological	c	-.37$	.23#	.15+	-.39$	-.39+	.19+
Resources	o		GOOD*	good	POOR*	POOR#	MIXED
	r		!!	!!	!!		

Notes appear at the end of the table.

Technological Capabilities and Functional Correlations

	.	..ALL..	.......Market	Orientation.......		....BoI Promotion....	
	a	.Firms.	Domestic	Both	Export	Yes	No
	S						
	c	.58$$	-.06+	.01_	.04_	.13$	-.13+
	o		poor	AVERAGE	AVERAGE	good	poor
Production	r					!!	!!
Capability	C	.32$$	.29$$	.43$$	.31$$	.17$$	.30$$
	r		AVERAGE	HIGH	AVERAGE	LOW	AVERAGE
	l					!!	!!
	n				min inv	inv	
	S						
	c	-.88$$	.15+	.10_	-.26$	.08#	-.08+
	o		good	good	POOR#	good	poor
Major Change	r		!!	!!	!!	??	??
Capability	C	.28$$	.46$$	.03_	.47$$	.19$$	.39$$
	r		HIGH	LOW#	HIGH#	LOW	high
	l		??	??	??	??	??
	n			min	inv res		
	S						
	c	-.04_	.24+	.09_	-.33$	.06_	-.06+
	o		GOOD#	good	POOR#	good	poor
Minor Change	r		!!	!!	!!		
Capability	C	.33$$	.47$$	.10*	.76$$	.28$$	.36$$
	r		HIGH#	LOW#	HIGH*	low	high
	l			!!		??	??
	n						
	S						
Investment	c	.12_	.0-+	.0+_	.0-_	.04_	-.04+
Capability	o		AVERAGE	AVERAGE	AVERAGE	AVERAGE	AVERAGE
	r						
	S						
Technological	c	-.37$	.15^	.22#	-.37$	.23$	-.23+
Resources	o		good	GOOD#	POOR#	GOOD#	POOR#
	r		??			!!	!!

Notes appear at the end of the table.

Table 12.C

Technological Capabilities and Functional Correlations *(Notes)*

Sources: Westphal (1989), Table 21, and later computations.

Notes: a -- Row titles appear vertically in this column; Scor (i.e., score) denotes estimate of relative technological capability; Crln (i.e., correlation) denotes estimate of functional correlation.

Scor -- Numerical values: first column, estimate of population average score; other columns, estimate of score differential for sub-population. Under Ownership: In the Thai and Foreign cells, the first value is for ElecTech; the second, for BioTech and MatTech combined. Values in the Foreign cells are exactly one-half of those in the Thai cells because two distinct types of foreign firm are distinguished in the underlying analysis.

$$, $, and * are as indicated below (using t-test); # indicates value greater than or equal to standard error of the estimate; !! [??] indicates that estimate appears quite robust [of questionable robustness].

Descriptive adjectives: based on quintiles of the distribution of all estimated score differentials shown in the table, see discussion in the text; * and # are as indicated below.

Crln -- Numerical values: highest adjusted — for degrees of freedom — R-squared among the corresponding capability regression specifications for which all estimated coefficients associated with the respective independent capabilities are positive <u>and</u> in which the number of such positive coefficients is the greatest. For production capability, the choice is made among specifications that exclude major change capability from the set of respective independent capabilities.

$$, $, and * are as indicated below (using F-test); # indicates value significantly different from zero at the 0.25 level; !! [??] indicates that null hypothesis of functional relationship's homogeneity across characteristic sub-samples can be rejected at the 0.01 significance level [can not be rejected at the 0.05 level].

Under Size: In the Medium and Small cells opposite Production Capability, ? indicates that the null hypothesis of the relationship's homogeneity between these two size classes can not be rejected at the 0.05 significance level.

Descriptive adjectives: reflect quintiles of the distribution of all adjusted R-squared's shown in the table (except those in the first column), see discussion in the text; * and # are as indicated below.

Words on the bottom line of each cell indicate, using abbreviated acronyms, the respective independent capabilities that are excluded from the underlying regression owing to negative coefficients associated with them; major change capability is not included in any of the underlying regressions for productive capability.

For numerical values: $$, $, and * respectively indicate that the value significantly differs from zero at the 0.01, 0.05, and 0.10 levels. A + indicates level of significance is not determined. A _ means nothing; it is there simply for proper spacing.

For descriptive adjectives: * and # respectively indicate that the associated numerical value differs from the average of all such values shown in the table by more than one or two standard deviations.

Totals may not reconcile due to round off error.

See the text for additional details regarding the contents and interpretation of this table.

Table 13
Sketch of a Microscopic Approach to Policy Research

	IDENTIFICATION		POLICY
PAST AND PRESENT	ASSESSMENT OF PRESENT CAPABILITIES Objective: Determine the nature and effectiveness of existing capabilities, in preparation for identifying key capabilities and for analyzing past technological development. Method: Survey of existing producers and local suppliers of technology in the key sectors; survey to use broad sampling frame and ask general questions. Responsibility: Shared effort between economists and technologists.	⟹	ANALYSIS OF PAST DEVELOPMENT Objective: Develop understanding of the factors influencing technological behavior by market and public agents, for use to uncover possible needs for policy changes and direct actions. Method: Field research to obtain case-histories of selected technological events / 'non-events' for analyzing the choice and transfer of technology and the dynamics of technological change. Responsibility: Economists, with technical support from technologists.
	⇓		⇓
FUTURE	CHOICE OF FUTURE CAPABILITIES Objective: Identify selected capabilities that should be developed, both for their own sake and to use as cases for analyzing future policy needs. Method: Sequential economic and technical evaluation to select appropriate technologies in specific sectors, and then to determine key capabilities needed for their efficient use and effective means for their development in proper phasing over time. Responsibility: Technologists, with technical support from economists.	⟹	POLICIES FOR ACCELERATED DEVELOPMENT Objective: Determine the need, and make recommendations, for reforming policies and public agents — and for new initiatives — in areas that have direct and indirect impacts on the rate and direction of technological development. Method: Generalization from case studies of key capabilities, using knowledge of past technological behavior to isolate which capabilities would not be developed without changes in public interventions in markets, and then to determine the warranted changes in policies and actions. Responsibility: Shared effort between economists and technologists.

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