[redacted]

Research Center

School of Business and Public Administration
UNIVERSITY OF MISSOURI, COLUMBIA

THE NATURE AND SCOPE OF AGGLOMERATION EFFECTS OF CITY SIZE AND ADVANCED SCIENTIFIC TRAINING ON INDUSTRIAL RESEARCH LABORATORIES

by

John C. Murdock

NASA NGR 26 004 012

The Author is Professor of Economics
and Faculty Research Professor in the Research Center.

This manuscript was prepared as a part of the research activity under grant NGR 26-004-012 between the Business and Public Administration Research Center, University of Missouri, and the National Aeronautics and Space Administration

RESEARCH CENTER
School of Business and Public Administration
UNIVERSITY OF MISSOURI
Columbia

March 22, 1967

The Nature and Scope of Agglomeration Effects of City Size and Advanced Scientific Training on Industrial Research Laboratories

I

In a study on the location of inventive activity, Professor Wilbur Thompson was able to show that it was highly concentrated among that part of the population living in and about Standard Metropolitan Statistical Areas (SMSAs).[1] To the estimated 57 per cent of the population, as of 1945, which fell in this category, 90 per cent of the patents in sixteen important patent classes were granted.[2] He also concluded, somewhat more tentatively, that inventions are employment oriented and that they may be subject in greater measure to those economies of spatial agglomeration which are independent of a particular kind of process or product line than production is.[3]

It seems unlikely, in view of the strong statistical results he obtained, that Thompson's findings with respect to the metropolitan orientation of inventive activity can be upset. Moreover, his conclusion that inventions are employment oriented seems reasonable enough. There is, however, reason to be skeptical of his final conclusion.

The immediate reason for this, in addition to the limited statistical support it has, is a weakness of patent data for location studies. In so far as patents are granted to companies, they normally are granted by the patent office and credited to the location of the administrative office of the company--rather than the location of the research facilities or production facilities where the invention may in fact have taken place. The administrative offices of the company may or may not be located in the same place as the other facilities.

It is generally recognized that the locational requirements of administrative offices of business firms have much in common even when these firms are of different industries. The agglomeration economies independent of a particular process or product lines which Professor Thompson found may well reflect the locational requirements of these administrative offices rather than research.

This difficulty can be avoided by considering the locations of industrial research laboratories themselves. Such an approach has the further advantage that it permits the consideration of all industrial research activity whether it terminates in a patented invention of not. This is important since the use of patents is favored more in some industries than in others.

Still another advantage which results from addressing the industrial research laboratories is that there is reasonable assurance the research activity associated with them is conducted as an economically rationalized operation which should, therefore, be sensitive to the economic forces of location. Thompson's result showing an occupational orientation of inventions could simply mean the inventor's job tied him to a location, rather than that inventing as such is oriented to locations where employment is large in the same industry.

There is one influence which may cloud the rational location of laboratories, however. About 86 per cent are divisions of manufacturing or other industrial enterprises. The location of these laboratories may be influenced by the location of other facilities of the organization to which they belong. Differences in the organizational structure to which the laboratory is committed need not necessarily alter the latter's location irrationally. Given the same "market" and performing the same functions with the same resources, whether the laboratory is independent or is an arm of a manufacturing firm--a "captive" so to speak--should not alter the optimal location for the research activity. In practice, however, it may be expected that there are at least some instances in which a "captive" laboratory is located exclusively to the accommodation of other elements of the enterprise.

Such cases seem likely to be most frequent when the owning firm is small and confined to a single location. Investment in a new, separated facility might constitute a risk which the firm does not wish to face, even at the cost of less effective research--although such a cost may not in fact be counted.[4] In these instances, however, it would not be likely that the shift from an optimal location to the location where the laboratory has actually been situated would often mean a change in the local area. And since it is the characteristic of the local area which this study is addressing, it is believed this disturbing consideration will constitute no serious problem.[5]

In addition, historical accident and essentially random selection are commonly credited "explanations" for the location of research. It must be anticipated that some industrial research laboratories, like other evidences of research, have been subject to such influences on site selection. The picture of research location is also clouded by these cases somewhat. But where such procedures for location result in important, adverse influences on costs or on the productivity of the research activity they normally do not go uncorrected. There are reasons to believe that the economic forces of research location are powerful and that they act to influence not merely the initial decisions of location but the ultimate survivors. The logic of location, therefore, may be expected to provide sufficient illumination of the overall pattern of research location, not withstanding these obfuscating circumstances, to permit us to recognize it as a rational structure. In the light of this, the industrial research laboratory was selected as the elemental unit of this study.

The primary objective of the analysis is to see if these laboratories experience net external effects of agglomeration. Although it is not intended to parallel Thompson's, the analysis will have something to say about some of the locational factors affecting research which he attempted to discern. If external effects are found to exist an effort will be made to identify the source and particular form in which any such effect presents itself to the laboratory.

An external effect which is found in association with a change in the size of the local economy and which is generally available to all local units of firms in all industries will be termed an urbanization effect while one which arises out of the local concentration of a particular industry and is available only to units in that industry is identified as a localization effect. These terms will be employed to distinguish the sources of external effects . Urbanization and localization are subsets of agglomeration.[6]

II

As a procedural matter several questions may be posed to focus attention on more specific points for consideration. These may then readily be modified, as desired, to serve as working hypotheses. The questions in which we are interested are: Do external effects of agglomeration exist? If so, can the form of agglomeration, urbanization or localization, be distinguished? And, lastly, in what facets of the laboratories' operations might external effects appear?

Before these questions can be fairly addressed, a number of clarifying steps must be taken. The first of these involves a further delineation of the concept of agglomeration.

A third type of agglomeration effect, called effects of large-scale, is associated with the size of the operation of a single decision unit at a particular location. Large-scale effects, unlike the locational and urbanization effects, are internal. If effects of agglomeration are found to exist for industrial research laboratories and if these are also found to be associated with this form of agglomeration effects, external effects for laboratories might not be involved in agglomeration.

To test whether the effects of large-scale are systematically associated with agglomeration, it was hypothesized that the size of laboratories did not vary significantly with the size of cities or with the magnitude of local facilities for advanced training in science. Using laboratory employment to represent laboratory size, standard metropolitan statistical area or county population as appropriate to constitute a general index of agglomeration and local Ph.D. production (1951-60) to represent advanced training in science, simple correlation coefficients were computed. The null hypothesis is easily sustained at the .05 level by t-tests for both the variable of city size and the training variable.[7] Both coefficients are small; one is negative . . It is concluded, therefore, that if effects of agglomeration are discerned by this study, they must either be locational or urbanization economies.

This result does not imply the existence of external effects to industrial research from agglomeration to be sure. But if they are found, there is some confidence that they are of an external nature. On this basis, we may now, for convenience hypothesize that external effects of agglomeration exist for industrial research laboratories.

Categories of agglomeration, as conceptual types, have been established above. But it is necessary to adopt the specific forms of agglomeration which can be used for measurement. The two forms employed are urban concentration and advanced training in the sciences. These will be discussed in detail later in this section.

Regarding the particular form in which the external effects might appear, it was apparent that inasmuch as some of these effects may not move through the market, they would not likely be caught with inquiries as to prices or costs relating to the laboratory's operations.[8] A more encompassing response would be required. To assure that the interpretation would not be too narrowly circumscribed, it was decided that an attempt would be made simply to discern whether a location conferred advantages or disadvantages with respect to each of a series of conditions relating to the conduct of research by the laboratories.

If an advantage were an external economy of urbanization or localization, it would not be available at non-agglomerated locations. Given the fact that there is considerable variation among laboratories, if agglomeration economies are sufficiently important the laboratories in agglomerated locations would, as a group, be expected to report a higher ratio of advantages to disadvantages with respect that element of their operation from which the effect emerges than the corresponding ratio reported by laboratories in non-agglomerated centers. The question seen in this light becomes one of whether the elements in which the urbanization and localization effects might appear can be sorted out and then evaluated as representing particular forms of agglomeration effects to laboratories in different types of locations.

The next question to arise is who would be able to ascertain and evaluate such variations in the conditions of the laboratories most effectively? The answer is clear enough. It would be a person at the immediate location who was charged with administering the laboratory's research operation. Such a person would need to take care to see that the requisite quality of activity was maintained within the constraints of a budget. This, obviously, would be the research laboratory director and it was decided to request information of these directors since no secondary data of the nature required was available. Nevertheless, it should be recognized that this procedure necessarily presumes that the directors understand the operation of their laboratories well enough to recognize how various facets of operation are affected by their location.

Precisely what should be asked of them and the form in which it should be asked was a further, and somewhat more difficult, exercise in judgment. It was, however, felt that questions should focus on particular facets of the operation of the laboratory with the request that the item be appraised exclusively on how the laboratory's location related to it.

If the director believed some aspect of his laboratory's requirements were adversely and substantially affected by its location, this was to be indicated as a substantial disadvantage. If he viewed his location as having a substantial advantage in a particular facet of importance to the laboratory, this should be indicated. But directors were asked only to indicate advantages or disadvantages if they were substantial ones. It is believed this format encouraged laboratory directors to make a comparative appraisal of the conditions in their location with other locations where research was being conducted.

By specifying particular features of the laboratory's operation identification of the effects of agglomeration was simplified. Even more importantly, was useful in attempting to distinguish urbanization and localization economies. (The items are listed below in Table 1.) It should be clear that the directors may choose to record responses (disadvantages) that would be read as evidences of external diseconomies. In separating the economic elements of the laboratory's operation into several parts it becomes easier to isolate any such effects. Thus, the danger that counter effects of agglomeration, working on different aspects of the laboratory's operation, might all go unnoticed because their influences cancel each other is substantially reduced.

The reader should, however, remember that the study specifically addresses external effects arising out of agglomeration. Although with one exception (to be discussed momentarily) the elements included in the list presented to the laboratory research directors were selected to try to reflect external effects, the directors were not asked to try to isolate such effects themselves. This latter task is reserved for statistical tests on the data received from the directors. It was believed possible that both economies and diseconomies of agglomeration might appear in the elements included in the list but the overall result of the study can only be read as the net of all external effects of agglomeration with some caution.[9]

There is always some chance of unrecognized bias entering an attempt to establish an unbiased procedure. For this reason one of the environmental elements included in the list sent to the research directors was introduced as a control item. The item in question is: the level of community services.

Included in this item are the public services of the local community such as police and fire protection, elementary and secondary schools, utilities, etc. Evidence from a number of previous studies suggest that as a group, the quality relative to cost of these services is probably not significantly associated with size of the urban center and--although no empirical studies are known to have addressed it--there appear to be no grounds for expecting any such association between the quality relative to cost of these services and the local commitment to advanced training in science.[10] It was felt that this item would offer no basis for the appearance of an external effect in association with the variables against which it would be tested. If none appear, this would provide some confidence that a hidden bias did not plague the procedure used in the study. Results of tests presented subsequently (See Tables 2, 3, 4) indicate no significant evidence of external effects exist so that the existence of procedural bias is not likely.

Attention is now turned to the agglomeration variables, the first of which is size of city. Interest in this variable arises from the generally acknowledged proposition that metropolitan areas offer a wider range of services and ancillary activities than non-metropolitan local economies.[11] To particularize our earlier hypothesis regarding external effects it may be taken, first, that industrial research laboratories obtain external economies of agglomeration in metropolitan areas which are not available to laboratories in smaller urban centers.

A distinction is also often made between the ordinary metropolitan area -- which is capable of "providing a satisfactory administrative unit for a number of public services. . . Such a population also might be expected to support a satisfactory University . . ."[12] for a region--and what may be called the "super" cities. The latter are thought to be mature, oriented to national or international markets in markedly larger degree, less dependent upon the performance of their region for growth, and among the few largest cities of a large modern economy.[13]

Inasmuch as research is a highly sophisticated activity, and in view of its considerable concentration in these "super" cities, a second, further, hypothesis may be offered: that the super cities offer further external economies to research than are available in the lesser metropolises. Both these hypotheses appear to enjoy considerable implicity acceptance.

While it would not support the hypothesis, possible sources of external diseconomies also exist. To congestion and what communications theorists term "noise" or, generally, disturbances, there may be added organizational problems of the larger urban center, not to mention the possibility of higher prices for inputs.

Size of course is not a wholly definitive indicator of the qualities associated with differences in city organization and function. The minimum population size required for a city to become a metropolis is arguable. Most observers agree that the Census definition of 50,000 persons is too small.[14] Florence placed the minimum figure at a million inhabitants for metropolitan status while Duncan cited certain cities with some metropolitan functions which had populations at the time of his study around 400,000 or even less.[15] Clark used 175,000 to 200,000 as minimal for a regional metropolitan center.[16]

It is clear from this that any figure chosen will be subject to criticism. For this study a population of 250,000 as the minimum size for metropolitan areas was adopted, nevertheless. It may be argued that this figure is a bit too low (or too high) but it is clear that cities of this size and larger are of a different character in the vast majority of cases from the smaller cities and towns in which research is located. When a community reaches this size it has developed substantial local markets and often will demonstrate at least some characteristics of metropolitan areas so that the quarter of a million figure can serve effectively as a watershed.

The division between the "super" cities and other metropolitan areas is placed at three million. This figure is not only convenient because it is about mid-way in a break between city sizes but, more fundamentally, it classifies cities in keeping with the abovementioned distinguishing characteristics.[17]

The size of the city is taken to be the population of the Standard Metropolitan Statistical Area (SMSA) or county in which each laboratory was located. Population figures were obtained from the <u>1960 Census of Population</u>.[18] Although the use of county figures overstates the smaller cities' populations somewhat, this was not an important consideration since it did not affect the groupings used for size of location. County figures were used in preference to those for cities or towns in order not to bias results by missing nearby populations which would have been included in an SMSA but not in a city below SMSA size.

The other agglomeration variable considered in this study is local facilities for advanced training in science. Somewhat different considerations from those mentioned in connection with city size lie behind the use of this variable.

A tie between scientific research and advanced training in the sciences is generally accepted and need not be adumbrated here. It is reasonable to expect that the existence of facilities and the manpower required for an active program of advanced scientific training produces a number of conditions in the local environment which are favorable to research laboratories in the area. In so far as such training, for example, requires indivisible or lumpy inputs which are common to both research and advanced training in the sciences, economies may be available to the nearby laboratories. Such items as libraries, specialists both at the professional and technician levels would appear to constitute examples of this kind of lure. But it may be expected that the possibilities for professional communication exchanges for the laboratory personnel in such locations would be of considerable importance in a larger center. In addition, these locations may offer an aura of prestige which is useful both in attracting personnel to the staff and in "marketing" the research output of the laboratory. Finally, the most obvious connection is in the employment of graduates of the educational facilities.

An apparently widely held belief is that such benefits as these are conferred in exceptional degree upon laboratories that are located where programs in advanced scientific training produce a very large number of scientists. No one really suggests that the quality of programs in advanced scientific training is a unique function of the size of these programs but there seems to be a general agreement that quality is related in a significant and positive way to size.

It may be suggested, for example, that the reputational benefits from local scientific training facilities rise disproportionately at the very largest centers for advanced training.[19] It may also be argued that these very large centers not only enable the achievement of the threshhold level of personnel with interest in a particular specialty or problem area but permit assembling many such groups in a variety of related interest areas. Each such group is an efficient unit for the generation of ideas and insights by those involved and the existence of other similar groups in the immediate environs stimulates the process of cross-fertilization. Because of these considerations it is reasonable to distinguish both the locations which lack advanced training facilities from those that do have such facilities and within the latter group between those that constitute the very largest centers for advanced scientific training from other centers.

On a basis of this reasoning, a third and a fourth hypothesis may be advanced: That the environment for the industrial research laboratory is more favorable where one of the other products of the local community is professional research personnel and that the environment at those centers which are the very largest provides a significantly more favorable climate for the industrial research laboratory than other locations, including those which have smaller programs in scientific training.

While, generally, the possibilities for external diseconomies to research laboratories from this agglomerative form appear to be more limited than from urban agglomeration, they do exist and it should be recognized that they may appear in the results of the study.

As an index of the commitment of the local economy to advanced training in the sciences, the cumulative aggregate Ph.D. production for the period 1951-1960 in all the biological and physical sciences (excluding psychology) of the relevant SMSA or county has been employed.[20]

The aggregate production of Ph.D.s is an output measure which does not permit direct consideration of quality differences in the training process which undoubtedly exists. In so far as resources commitment increases with increases in the quality of the Ph.D.s, the index of Ph.D. production introduces error in measurement. Since there is reason for believing that quality of Ph.D.s is not negatively associated with the quantity of Ph.D.s produced, any such error would understate resources committed at the larger agglomerations. However, some quality improvement associated with the magnitude of the center is achieved without proportionate increases in inputs. The efficiency with which certain specialized inputs can be utilized increases with the size of the local training effort--especially in the smaller centers. Ph.D. production then is a proper reflection of input--though a less satisfactory index of output, which we fortunately do not require.

Some quality improvement associated with size, nevertheless, may reflect disproportionate increases in the level of input commitment per Ph.D. produced. It is not known how large this may be, but if external economies are associated with the level of such resources, the error would cause the relation of resources committed to external effects to appear somewhat more pronounced than, in fact, it is. If, however, no external effects are demonstrated, we will know that the result was in spite of a possible error which tended to overstate such effects.

Locations were grouped in terms of Ph.D.s produced as follows:

0 - 10 Ph.D.s produced during the period 1951-60

11 - 1500 Ph.D.s produced during the period 1951-60

More than 1500 Ph.D.s produced during the period 1951-60

Reduced to annual averages, locations falling in the first group produced one or fewer Ph.D.s in all sciences. It seems evident that such an area had quite limited or no facilities for providing advanced training in the sciences. Communities of the second group produced between one and 150 Ph.D.s per year on the average. This covers a wide range but there is reason to feel that these localities have at least some facilities for advanced scientific training so that if this is a significant element in location it should be evident in the responses from research directors of laboratories in such places. Finally, the last category includes those whose annual production of Ph.D.s in the sciences is over 150 and range up to approximately 300 per year. Centers with facilities this large would have to have a very high commitment of resources to such programs. There are comparatively few locations which qualified for this category and these locations embrace some of the leading institutions of higher learning in the country. It is reasonable to believe that locations in this last group represent exceptionally strong centers for advanced scientific training.

As with the city size variable, the lines for demarking these three groups can only be defended on the grounds that they approximate the distinctions which are sought. The exact location of these lines is not likely to affect materially the results, however, and the limits of the classes are sensible ones for defining the desired categories.

A sample of 475 laboratories was drawn from Industrial Research Laboratories of the United States, 1960.[21] This constituted about 9 per cent of the total number of laboratories listed.[22] A questionnaire was mailed to all laboratories in the sample. Two hundred thirty four laboratories or 49.3 per cent of the laboratories provided usable responses to the series of questions dealt with here. This is a high effective response to a mailed questionnaire to industrial addresses and after certain tests were made it was concluded that the respondents constituted a representative and unbiased sample of all industrial research laboratories.[23]

The responses required evaluation by the director of the laboratory but possible answers were restricted as noted so that questionable cases were included in the category of neither a substantial advantage nor disadvantage. This middle category of responses, which ran from a low of 8.98 to a high of 27.35 per cent of the total, was then eliminated from further consideration and analysis concentrated on those cases where the laboratory directors indicated the location conferred a definite influence on the environment of the laboratory.[24]

The responses indicating a substantial advantage or substantial disadvantage were then tallied for each item by size of city category and by Ph.D. production category and 2 x 2 contingency tables were constructed for each. Chi-square tests were then made to ascertain whether there were significant differences in the responses from laboratories in different city and Ph.D. production categories. When the Chi-square values were found to be significant ($\chi \leqslant .05$) the Contingency Coefficient (C) was computed so that the relative level of association of each of the significant associations might be compared.

A final comment on procedure is necessary. The date of the responses of directors of research laboratories lagged the population data and the final date for the Ph.D. production data by five years, having been collected in 1965. This lag was not sought and ideally it would have been avoided but this was not possible. The secondary sources did not provide data for 1965 and it was thought less reliable to ask respondents to attempt to recall the particular conditions pertaining five years earlier than to ask them to respond on current conditions.

The lag is not as serious as it might be with other phenomena for two reasons. First, there is some lag between the actual locational conditions and the attitudes about those conditions. Just how long the lag is may be expected to vary with the particular aspect of location involved. Second, the variables of city size and advanced training in science are altered only slowly. A five year period is not likely to reflect drastic increases or decreases and the relative position of individual locations is even less likely to be materially altered because the trends in both population and training, for most of the cities involved, are in the same direction.

III

The percentage of total respondents indicating substantial locational advantages and disadvantages for ten locational elements of their environment are shown in Table 1. Items 1 through 7 concern various aspects of supply of inputs for the laboratories. These are self-explanatory. Items 8 and 9 purport to provide some insight about how the location affects the laboratory's market. Access to production facilities is to be interpreted as an index of the ability of the laboratory to obtain intimate knowledge of the technical needs of its customers. Size of market is an inquiry as to how the location is thought to influence the number of customers and the amount of research they will fund.

The final item in the list, prestige of region, was included with some reluctance because the region could not be precisely delimited. Beyond this, it is at a different level from the other factors included in Table 1. It does not seem to fit comfortably or at least not directly into a supply and demand framework. It is, nevertheless, involved in the valuation of a location and may be expected to exert an influence on at least some of the other items in Table 1. In this sense it duplicates other items in part but its shadow falls across several while offering a complete basis for none of the others.

Prestige on the surface appears to be affected by many things. Ultimately, among professionals and industry, however, it is performance that engenders prestige. This means that a region enjoys a prestigious reputation among those most relevant to this analysis because of the type and quality of the research performed in the region. It should be clear that at any moment the prestige of a region is more than the collective reputations of its scientists. This is because a region's prestige is influenced by its history as well as by its current scientific occupants.

Consideration of the prestige of a region, extends the scope of locational factors to include the question of how important the research product of the region is to the laboratory. This holds significance not only because of its influence on the size of the market it helps attract but because of its effects on inputs, with special reference to personnel.

Of course it would be foolish to suppose that regional prestige either set a ceiling or a floor on the performance of an individual's research or that of a laboratory. Yet it must be recognized that a laboratory might gain advantages or suffer disadvantages by being equated by some persons with the prestige level which its region has for research.

It is apparent from the percentage of total responses indicating substantial effects of location that either the directors feel the influence of the local environment on the elements included in Table 1 is pronounced or that, as a group, they included comparatively small advantages and disadvantages from the local environment in their responses. Given the very high level of total responses crediting the local environment with influence of a substantial level in virtually all the elements in the table, even conceding that comparatively small advantages and disadvantages were included among responses still leaves considerable substance for the alternative explanation. This is to say, it appears that the local environment is considered a highly important factor in determining the desirability of a research location.[25]

This interpretation is further supported by the fact that what may be called the 'traditional' locational considerations are of limited or even negligible importance in

TABLE 1

Responses Indicating Characteristics of Locations by Directors of Industrial Research Laboratories

Elements of Local Environment	Substantial Advantage	Substantial Disadvantage
1. Supply of Professional Research Personnel (Ease of recruitment and retention of staff)	44.87%	27.78%
2. Supply of Technical-Level Personnel for Research	66.24	23.43
3. Level of Supplemental "Outside" Research Facilities (including all facilities and personnel outside respondent's organization, such as other laboratories, universities, libraries and other information sources, and availability of special research equipment on rental or fee basis.)	75.21	15.81
4. Supply of Research Materials, Equipment and its Servicing.	71.37	15.38
5. Level of Urban Facilities (such as financial, business, and other non-scientific professional services, specialty suppliers, cultural activities, recreation, etc.)	78.21	10.26
6. Level of Urban Community Services (such as police and fire protection, elementary and secondary schools, utilities, etc.)	79.06	8.55
7. Level of Transportation and Communication Facilities	72.65	16.24
8. Size of Market for Research (Respondents were advised to consider all appropriate sources of potential funds for research, such as private industry, government, foundations, other laboratories, universities, etc.)	56.41	19.66
9. Access to Production Facilities (of those using the research results of the laboratory	72.65	17.52
10. Prestige of Region	60.68	19.23

the selection of a site. Resource deposits, procurement and distribution transportation costs, even the interaction of competition appear to have less meaning for research laboratories than for many other forms of economic activity. Given these circumstances, the remaining rational economic considerations would reasonably be expected to be given disproportionately heavy emphasis.

IV

Results of the Chi-square test concerning city size are shown in Table 2. These results provide confirmation of both hypotheses concerning city size. Responses from laboratories located in cities smaller than the metropolitan size class contain a significantly lower ratio of advantages to disadvantages of location on several elements of the laboratories' economic environment than responses from laboratories located in cities of the 250,000-3 million class. In turn, the ratios for the latter laboratories are seen to have tested significantly lower on several items than for laboratories located in the so-called super cities with populations exceeding 3 million.

The results, however, bear closer scrutiny if their full meaning is to be correctly interpreted. Consider the comparisons for the smallest and intermediate classes of cities. The industrial research laboratories attain external economies in a variety of aspects of their operations as the size of the city in which they are located increases. But it is to be noted that between the laboratories in the smallest city size class and those in cities of the next category, the technical or professional aspects of supply considerations stand out as elements in which these economies appear. Every one of the items relating to the technical inputs for the laboratory (supplemental research facilities, research materials and supplies, supplies of professional and technical research personnel) offer such economies. The only additional item which similarly gives indication of the existence of an agglomeration economy is the prestige of the region. As noted earlier, the locational advantage offered a laboratory by the prestige of its region is associated with the type of quality of the research in the region. Prestige is not a technical matter itself and does not involve an input but it is generated by professional evaluation of technical conditions, notably output, and prestige has impact on the supply or availability of at least some of the laboratory's technical inputs--particularly its personnel.

Thus while there are clear indications that city size is associated with external economies for the laboratories, the nature of these economies, as indicated by the points at which they emerge, is clearly that they are specialized for research rather than general for all industry. The technical orientation they exhibit strongly suggests that, although they have been found in statistical association with city size, these economies are uniquely available to research activity. In short, we have found a number of localization economies.

While we do not have effective data available for measuring the level of local research which might serve to provide further substantiation of this proposition--had it been available it would have offered a much more direct approach to this conclusion, of course--we do know that such evidence as is available indicates considerable concentration of research work in larger urban centers.[26] This would be compatible with the requirements for the external economies in question to be of the nature of localization economies. With this additional information, the results from Table 2, therefore, seem to provide a satisfactory basis for our conclusion.

Focussing on another aspect of the figures from Table 2, they indicate that even in cities below metropolitan status, laboratories probably can obtain the requisite non-professional and non-technical inputs about as readily and satisfactorily as laboratories situated in intermediate size urban centers. The items that would

TABLE 2

City Size in Association with Several Elements of Local Environment for Industrial Research Laboratories

Elements of Local Environment	X^2 values of differences in responses from laboratory locations grouped according to city size class: 0-250,000 vs. 250,000 - 3 million	250,000 - 3 million vs. over 3 million
1. Supply of Professional Research Personnel	.001	.05
2. Supply of Technical Level Personnel	.001	Not Significant
3. Supplemental Research Facilities	.001	Not Significant
4. Research Materials and Supplies	.001	.02
5. Urban Facilities	Not Significant[b]	Not Significant[b]
6. Community Services[a]	Not Significant	Not Significant
7. Transportation and Communications	Not Significant	Not Significant
8. Size of Market	Not Significant	.05
9. Access to Production Facilities	Not Significant	Not Significant
10. Prestige of Region	.01	Not Significant

[a]Community Services represented a control item which should not have shown significance if the test were unbiased.

[b]Insufficient observations for valid test but tested not significant. The Chi-square test between the 0-250,000 and 250,000-3 million groups yielded a value of 2.84, well below the .05 significance level. The low cell had theoretical observations of 3.76. The test between the 250,000-3 million and the over 3 million groups yielded a value of 1.37, the low cell having 4.53 observations. Since the Chi-square value is likely to be too large as a result of cells having too few observations, specifying these results as not significant is a reasonable interpretation.

ordinarily be thought of as points where urbanization economies would appear--the community services, urban facilities, transportation and communications--none of these appear to offer external economies to the laboratory.[27] There is no significant evidence of urbanization economies associated with the supply relationships of the research laboratories within the smallest and the intermediate city size categories.

In comparing the changes between the intermediate sized and super cities, the structure is generally the same. Two points should be mentioned at which variations from the pattern appear, however. First, several of the elements that showed significance between the centers of less than 250,000 and those between 250,000 and 3 million population, fail to yield a significant difference in the responses between laboratories in the latter group of cities and those in the cities over 3 million.

Necessarily this means a reduction in the frequency with which locational economies appear as the larger size categories of cities are compared since these were the only external economies found between the smaller and intermediate size categories of cities. If these externalities are the result of certain indivisibilities (as might explain the input or supply items, if not the matter of prestige), then it appears that those remaining items showing a significant difference in the response ratios between cities of the two larger size categories involve elements of research operations in which the matter of indivisibilities are most important. The elements in question are, predictably, supply of professional research personnel but, surprisingly, supply of research materials and equipment and its servicing. The appearance of supply of research materials and equipment does not refer to internal use of materials and equipment and does not involve internal economies. Neither does it refer to the availability of local equipment on a lease, rental, or borrow basis. It rather refers to the influence of the location on the ability of the laboratory to obtain these inputs and the servicing for them. Why the location should be of particular importance where the market for the commodities involved appears to be national and involves goods which are shipped without undue difficulty is hard to explain unless the matter of service is transcending. This may be the case but the author is not persuaded.

The other change of note is the appearance of a significant difference in the size of market or availability of sources of funds. This relationship is different from the others previously considered in that it is associated with an element on the demand side of the ledger. It also differs by making its appearance only when the cities are large. It is quite the reverse of some of the agglomeration economies associated with supply elements in this connection.

Within the tools at our disposal there is no satisfactory way to catalogue this agglomeration economy as one of urbanization or localization. (Does the growth in availability of sources of funding reflect the larger general market of the city or specifically is some unique feature of research itself involved?) For what it is worth it can, with some assurance, be said to result from an indivisibility. But to pronounce this is scarcely to offer an explanation in any of these cases. It amounts to little but a very general description.

Perhaps the most important thing about the effect of differences in city size on size of market, for present purpose, is that it indicates how comprehensive the influences of the city can be. The city economy, even if it fulfills no more than the passive function of housing a research laboratory, constitutes the environment of the location in large part. The change in its composition with difference of size either by directly limiting or altering the form or conditions which inputs may take or the level and nature of demand or by indirectly establishing other conditions which effect the same kinds of results, may engender or smother external economies to the laboratory. The city can, therefore, be an important reference to which even localization economies are dependent.

The final point to be made in connection with city size is simply that whenever agglomeration effects are discernible between cities in different size groups, they are invariably economies which favor the laboratories in the larger cities. While diseconomies to individual laboratories in the largest city size category undoubtedly exist, unfavorable responses associated with any of the 10 elements in Table 2 are never a significantly higher proportion of total responses for the group than the proportion for laboratories in either of the smaller city size groups.

Within the confines of the elements of research location encompassed by this study, the evaluation in summary is that net economies of agglomeration are associated with city size throughout the size range covered. These are, for the most part--and perhaps entirely--localization economies, however, rather than urbanization economies. The importance of analyzing the relationship between these economies and city size, therefore, appears to be one of trying to find out simply how effectively and readily research activity (as an economic sector) can be organized within local economies of different sizes. It seems clear that the size of city has been found to be a relevant consideration in the ability of industrial research laboratories to obtain agglomerative economies. Just exactly how the changing structure of the city is related to the actual sources of the locational economies and just how important these economies are remain unanswered.

V

In Table 3 the results of Chi-square tests involving the various elements of the industrial research laboratories' operational environment and local Ph.D. production are shown. The number of associations which tested significant are seen to be substantially fewer than was the case with city-size--exactly, half as many. Inspection of the contingency tables indicated that like city size, Ph.D. production produces no suggestion of external diseconomies.

Because local Ph.D. production is an index of an activity considerably more specialized than the aggregate of activities reflected by city size, it is not unexpected to find no evidence to indicate urbanization economies are available to the research laboratories. On the other hand, the kinship that advanced training in science has to research suggests that Ph.D. production would be a more sensitive measure for localization economies, wherein the growth of a sector provides external economies to the individual units of which it is composed, than would city size. Comparison of Table 3 and Table 2 fails to confirm even this, however. Advanced training in science is apparently a less sensitive measure here as well.

Only three of the 10 elements of the labs economic environment are shown to be significantly affected by variations in the level of Ph.D. production between those localities which have negligible Ph.D. production (0-10) and those which offer a modest to sizable Ph.D. output (11-1500).

Differences between this 11-1500 group and the very largest centers for advanced training in the sciences (more than 1500 Ph.D.s) virtually disappear. Only

TABLE 3

Ph.D.s Granted Locally (1951-60) in Association with Several Elements of Local Environment for Industrial Research Laboratories

Elements of Local Environment	Differences in laboratory responses grouped according to number of Ph.D.s granted locally: 0-10 vs. 11-1500 Ph.D.s	11-1500 vs. over 1500 Ph.D.s
1. Supply of Professional Research Personnel	.01	Not Significant
2. Supply of Technical Level Personnel	.001	Not Significant
3. Supplemental Research Facilities	.001	Not Significant
4. Research Materials and Supplies	Not Significant	.05
5. Urban Facilities	Not Significant	[a]Not Significant
6. Community Services[b]	Not Significant	Not Significant
7. Transportation and Communications	Not Significant	Not Significant
8. Size of Market	Not Significant	Not Significant
9. Access to Production Facilities	Not Significant	Not Significant
10. Prestige of Region	Not Significant	Not Significant

A probability of .05 or less for Type I errors is accepted as significant.

[a]Community Services represented a control item which should not have shown significance if the test were unbiased.

[b]Insufficient observations for a valid test but tested not significant. The Chi-square test between the 0-10 and the 11-1500 Ph.D. production centers yielded a value of 2.84, well below the .05 level of significance. The low cell had theoretical observations of 3.76. The test between the 11-1500 and the over 1500 Ph.D. production centers yielded a Chi-square value of 1.41, the low cell having 4.53 observations. Since the Chi-square value is likely to be too large as a result of cells having too few observations, specifying these results as not significant is a reasonable interpretation.

the enigmatic item of research materials, equipment and its servicing appears and tests significant at the .05 level while all items significant between the 0-10 and the 11-1500 Ph.D. output categories disappear. Even the remaining item of research materials and equipment is under some shadow in view of the earlier discussion which indicated Ph.D. production may tend to overstate the association between advanced training in science and external economies for laboratories in the largest category.

As might have been expected from the consideration of the results with the variable city size, the statistically significant associations between industrial research laboratories and local Ph.D. production is exclusively with inputs of a technical nature. The items relating to demand show no significant association. But it is clear that even in the relationships with purely technical inputs, the variable Ph.D. production suffers in comparison with city size.

One must conclude from an overall appraisal of the results from tests of these two variables that by all dimensions the external effects on research labora-troies of differences in the levels of Ph.D. production are distinctly more modest than those associated with differences in city size. Furthermore, the near total disappearance of indications of external economies in the comparison of the 11-1500 and the over 1500 categories of Ph.D. producing locations adds further testimony to the weakness of this variable as a source of external economies to laboratories. In no single element of the operational items tested does a significant association appear between Ph.D. production and the ratio of responses indicating advantages to disadvantages where an association between city size and the ratio of responses is not also significant.

TABLE 4

Contingency Coefficients (C) for City-Size and for Ph.D. Production with Response Ratios to Various Elements of Industrial Research Laboratories Operational Environment

Elements of Environment	C's for City Size[a]		C's for Ph.D. Production*	
	0-250,000 vs. 250,000-3M	250,000-3M vs. Over 3M	0-10 vs. 11-1500	11-1500 vs. Over 1500
1. Supply of Professional Research Personnel	0.313	0.178	0.258	---
2. Supply of Research Technicians	0.261	---	0.299	---
3. Level of Supplemental Outside Research Facilities	0.401	---	0.341	---
4. Supply of Research Materials and Supplies	0.263	0.180	---	0.170
5. Level of Urban Facilities	---	---	---	---
6. Level of Community Services	---	---	---	---
7. Level of Transportation and Communication Facilities	---	---	---	---
8. Size of Market for Research	---	0.157	---	---
9. Access to Production Facilities	---	---	---	---
10. Prestige of Region	0.212	---	---	---

[a]All Contingency Coefficients listed are computed from 2 x 2 Contingency tables and have a theoretical limiting value of 0.707.

In Table 4, the Contingency Coefficients (Cs) have been computed for all elements in which the Chi-square test indicated significant relationship. While there are only four cases where the C's for both variable are significant to the same element, in three of these four cases the C's associated with city size are higher--even though the margins are small.. Even though no tests of the significance of the differences between the C's are offered, they may be added to the other evidence suggesting that the relationship between agglomerations of advanced training for science and external economies for industrial research is weaker than in the case of urban agglomerations.

This evaluation of the results obtained in Tables 2, 3, and 4 should be considered in the light of an association between the two variables themselves. A Chi-square test confirmed the obvious association ($\alpha = .001$).[28] The Coefficient of Contingency (from a 3 x 3 Table) was .540. This value is difficult to interpret as an absolute measure of the level of association and cannot be read as a correlation coefficient. (The upper limit for C in 3 x 3 tables is 0.818.) It is, however, a moderately high value and well above the highest associations between city-size and the ratio of responses to individual elements of the lab's operations. (Although the values shown must be read differently from those from a 3 x 3 Table because the upper limit for a 2 x 2 Table is only 0.707.)

The fact that this association between city size and local Ph.D. production exists further weakens the case of the association of local Ph.D. production and economies of agglomeration. There is clearly a good chance that the associations which appear between Ph.D. production and changes in the ratio of responses may no more than reflect the association of Ph.D. production with city size.

VI

In view of the admitted diversity of laboratories and the variations of orientation which typifies their locational pattern, are statistical results meaningful even when these results meet the test of statistical significance? The answer is yes.

The lack of uniformity of response by laboratories to the various questions--even within given city-size or Ph.D. production categories--may be attributed to a wide number of influences but two are of major importance. First, cities even where they are approximately the same size, differ in the nature of their economies. A Pittsburgh and a San Francisco will have a different impact on laboratories. So will a New York and a Detroit. The composition of activities within cities in the same size range may be substantially different. This can mean that the level of advantages or disadvantages in particular facets of the laboratory's operation can vary from city to city within a given size category. This was, of course, acknowledged in considering the problem of establishing the categories in the first place. To a lesser extent similar variations in the educational complexes of the same general size certainly exist.

Clearly, laboratories reporting from a cross-section of such localities, even if the laboratories themselves were entirely uniform, would likely respond differently to at least some of the items. This does not provide grounds for rejection of the hypothesis that the essence of the community to the laboratory is affected by the community's size or by the size of its facilities for advanced training in science, at least not unless we find that the responses as between city sizes or training facilities levels are random. And this we did not find. Differences in cities within the same size categories so far as laboratories are concerned have merely reduced the relationships. They have not rendered them meaningless.

Second, the laboratories themselves are diverse. The inherent uniqueness of research has, indeed, stood as a seeming barrier to the analysis of research as an economically rational pursuit. Such heterogeniety could lead to essentially random geographic distribution of laboratories. But data have been presented which indicate quite clearly that this is not so. Moreover, if laboratories were wholly heterogeneous, the pattern of responses would not have given the clear indication of differences between cities in different categories which were obtained. Laboratory differences, like differences in cities, merely lower the level of the associations. They have not eliminated them.

Implicit in the recognition of diversity of both the localities where the laboratories are situated and of the laboratories themselves is the belief that other, non-agglomeration, locational influences are at work, some of which, at least, are presumed to be grounded in economically rational behavior. To have centered attention on agglomeration is not a denial of these other influences. It has rather been an effort to see whether or not the existence of economies or diseconomies for research laboratories arising from certain forms of agglomeration could be established and if so to ascertain at what points in the operation of these laboratories the influences might appear. Diversities, counter forces, non-rational influences merely have the effect of obscuring the existence of the influences which we have attempted to discern.

The results which have been obtained support fewer conclusions than may actually be warranted simply because it has not been possible to distill from this welter a clear liquid. We cannot pronounce, for example, that external diseconomies to laboratories are not associated with urban or training agglomerations. We can only state that none appeared within the sensitivities of the tests performed. Similarly, it would be inappropriate to assert that no further external economies of agglomeration accrue to industrial research laboratories beyond those which have been noted. All that can be said is that in spite of the acknowledged overburden of inert material and other difficulties, a significantly larger proportion of laboratories in the larger urban centers report substantial advantages relative to disadvantages with respect to several elements of their operational environment than are reported from smaller centers. These differences are read as reflecting economies of agglomeration. (They may be net of diseconomies, of course.)

This conclusion may be stated in another fashion. The quality of environment is improved to a significant number of industrial research laboratories with an increase in urban agglomeration. The points at which these economies appear very decidedly to relate to the technical aspects of laboratory operation, however, which suggests that their nature is that of localization economies as distinguished from urbanization economies. This is in contrast to Thompson's results.[29] It also suggests that if this is so, the essential element of agglomeration may be described more effectively than by city-size, since localization economies are associated with agglomeration of individual sectors rather than with the economy in aggregate.

The results of tests with advanced training for science--as indexed by local Ph.D. production--as the agglomerating agent proved disappointing. Distinctly fewer results of significance were obtained (only half as many as with the urban agglomeration tests) and those which were found generally did not compare favorably with the test results using city size as the variable.

One must remain somewhat skeptical of his own procedures and it is, of course, possible that with the approach taken here essential agglomeration effects on laboratories from centers of advanced training in science were somehow obscured. What makes this a less likely explanation, however, is that the pattern of externalities to the laboratories as between the two variables was dissimilar primarily in magnitude and extend alone, not in general pattern. Furthermore, the nature of the external economies should have been more easily picked up by the training centers than by city size because of the technical nature of the elements involved.

While many problems of studying the influence of agglomerations on industrial research are readily admitted, it is felt that the results indicating the existence of certain elements in the laboratory's environment from which external economies of particular type arise have been reasonably well established. As noted, there must be somewhat less confidence in so far as the results failed to show the existence of agglomeration economies at certain other points. But where, in the case of the variable facilities for advanced training in science, the procedure followed those which did indicate agglomeration economies associated with city size, we may be able to say with some assurance that the influence of the training center is not as great on industrial research as the influence of the urban center. Moreover, the similarity of the pattern of associations shown for Ph.D. production with that shown for city size, while consistently fewer and generally lower, gives weight to the proposition that advanced training facilities for science offer very modest external benefits for industrial research.

These observations carry with them implications for policy of some importance. Specifically, in view of the results obtained, the case--so frequently advanced in vindication of policy decisions on the allocation of resources as well as in the interpretation of the locational pattern of research--that research collects at the very largest centers of advanced training in the sciences because of substantial economies of agglomeration associated with the input end of research must be received with some considerable degree of uneasiness.

Finally, the absence of any indication of urbanization economies in association with either variable raises serious doubt as to the importance of amenities as a significant factor affecting the locational pattern of industrial research laboratories.

FOOTNOTES

[1]W. Thompson, "Locational Differences in Inventive Effort and Their Determinants," The Rate and Direction of Inventive Activity, R. Nelson, editor (Princeton: National Bureau of Economic Research, Princeton University Press, 1962), pp. 253-272.

[2]Ibid., p. 259.

[3]Ibid., pp. 264,266.

[4]Mueller and Morgan, "Location Decisions of Manufacturers," American Economic Review, May, 1962, have shown the considerable degree of locational inertia of small manufacturing firms.

[5]See Statistical Appendix, Section A.

[6]These concepts come to us via E.M. Hoover and Bertil Ohlin. Cf., W. Isard, Location and Space Economy (New York: Wiley, 1956), pp. 172 and elsewhere. A third form of an agglomeration, mentioned below in the text, spoken of as large-scale, produces internal effects on decision units.

[7]Data Sources: U.S. Census of Population 1960; Doctorate Production in United States Universities: 1920-1962 (National Academy of Sciences - National Research Council: Washington, D.C., 1963) Publication No. 1142, Appendix 5. With city size the correlation coefficient was 0.470 ($.60 < \alpha < .50$). With Ph.D. production the correlation coefficient was -1.342 ($.20 < \alpha < .10$).

[8]In particular, the technological external economies. This term was apparently first used by J. Viner ("Cost Curves and Supply Curves," Zestschrift für Nationalökonomie, Vol. III, (1931) reprinted in G. Stigler and K. Boulding, editors, Readings in Price Theory (Homewood, Illinois: Irwin, 1952)). The definition used here, as economies which are effected directly from the technical unit of production to the affected unit without first passing through the market for valuation is credited to T. Scitovsky , "Two Concepts of External Economies," Journal of Political Economy, April, 1954. Scitovsky , apparently set to looking over the countryside for examples by Meade's famous bee-keeper and orchard owner illustration (External Economies and Diseconomies in a Competitive Situation," Economic Journal, March, 1952) decided that there were but a few, bucolic examples and concluded that the technological external economies were not practically very important. He was, of course, looking in precisely the wrong direction. But others, including Viner, have noted the difficulty in identifying technological external economies.

It should be pointed out, however, that our interest is not exclusively with the technological external economies. The literature on external economies has traditionally been interested in the problems which the existence of these phenomena imply for market effectiveness in bringing private and social net product or cost into coincidence. (Cf., for examples, A.C. Pigou, The Economics of Welfare (fourth edition, Part II; London: Macmillan, 1948), chapter 10; J.E. Meade, "External Economies and Diseconomies in a Competitive Situation," Economic Journal, March, 1952; F. Bator, "The Anatomy of Market Failure," Quarterly Journal of Economics, August, 1958; J. Buchanan and W. Stubblebine, "Externality," Economica, November, 1962; O. Davis and A. Winston, "Externalities, Welfare, and the Theory of Games," Journal of Political Economy, June, 1962; R. Turvey, "On Divergence Between Social Cost and Private Cost," Economica, August, 1963.)

Since Meade, op. cit., it has been customary to express technological external economies in production functions as:

(1) $X_1 = X_1 (1_1, c_1; X_2)$

(2) $X_2 = X_2 (1_2, c_2)$

where X_1, X_2 are respectively the outputs of x_1 and x_2 of industries (or firms) 1 and 2

1_1, 1_2 are respectively labor inputs of industries (or firms) 1 and 2

c_1, c_2 are respectively capital inputs of industries (or firms) 1 and 2

Terms on the right side of equation (1) but to the left of semi-colon are ordinary inputs, subject to variation at the discretion of the using industry or firm. The term to the right of the semi-colon takes values assigned by the producing industry or firm--rather than by the using industry. It is this latter term which constitutes the external effect. X_2 is not purchased and sold; it does not enter the market.

All external economies arising in this manner are considered technological after Viner's definition, op. cit. The external characteristic of such economies arise from the vertical separation of decision units in a common production sequence where the vehicle carrying the external economy is an intermediate good. If industry 2 has a production function similar to industry 1's with an input of X_1 to the right of the semi-colon, the relationship is rendered more complex but remains internal to the broad production process which is involved in producting a joint-product.

Technological external economies may also arise in a different, and rather more interesting, case in which a common input exists for two or more industries or firms. An external economy for industry (or firm) 1 is tied in no direct way to the production process of industry (or firm)2. The tie of the two in this case is via their mutual demand for the input. Unlike the Meade type of external economy, these must be traceable to some indivisible aspect of the input in demand or the activity it performs. The effects of the indivisibility are overcome by the additional demand for the input coming from the second industry (or firm). If the input which is in joint demand by the two industries (or firms) is a primary productive factor, e.g., land or labor, its supply may reasonably be considered outside the production processes of the two industries utilizing it as an input.

Pecuniary external economies (i.e., those arising from a favorable shift of market prices of inputs or outputs of a producing unit) simply change the prices of inputs to the left of the semi-colon in equation (1) and would not alter the terms in the equation at all. This is because Meade and others have not been interested in the pecuniary external economies. Pecuniary external economies eminating from joint-demand of indivisible inputs similarly is accounted for in favorable price shifts of the input. Whether the economies appear as lower prices for inputs or advantages which are not recorded in the market is unimportant for the present study. The important consideration is not whether the market accounts for them but whether or not they exist. Urbanization and localization economies share the general reputation of being hard to identify. The difficulty is due in part at least to trouble in pinpointing their source. They are the consequence of growth of a local economy, either in the aggregate or in a substantial sector of that economy. As the external effects emerge they are not readily associated with individual decision units or activities. That they appear only slowly contributes to the lack of consciousness of their source or even of their existence. The fact that several small external economies may arise from the same source adds further to the problem of identification of source.

[9] One obvious item which would be expected to reflect external diseconomies of agglomeration is land space. This item is thought to be of comparatively minor importance for industrial research laboratories, however.

If land cost differentials among possible locations for a particular laboratory are large andimportant, land cost reduction would be sought, if necessary, at the cost of other locational advantages. A location without external economies might therefore be accepted if adverse land costs could be avoided. This might cause some shifting away from the larger agglomerations where, presumably, higher land costs would appear. There is no reason to believe, however, that it would distort the responses given by each laboratory concerning conditions where it was located in any significant fashion. Although there might be fewer laboratories in some locations than there would be if land cost differentials were not important, such a distortion would involve only negligible change in the sources of external economies indicated among the different locations as those sources are measured in this study.

But how important is the effect of land cost differentials likely to be on the spatial patternof research laboratories? Land costs can be put in perspective by relating them to the laboratories' overall costs.

From other data obtained in the survey of research laboratories it was determined that rent or interest on capital invested in land for the site of the laboratory cannot average more than about 5 per cent of the laboratory's total budget and there is reason to believe that this figure is an overestimate. If we accept a figure 50 per cent greater than this as the upper limit (7.5 per cent) with 2 per cent as the lower limit, the differential total costs is still only 5.5 per cent. This would permit the highest land costs locations to be 375 per cent of the lowest land cost locations, both expressed as a per cent of the laboratories' budgets.

But industrial research laboratories typically have considerable flexibility of location within a community. Their immediate requirements are not such that ordinarily they must locate in the sections of a city with the highest land costs. We should expect, therefore, that the extremes of land price differentials between localities would be avoided if land costs were a very important consideration in total costs to the laboratory. It would appear, therefore, that the 5.5 per cent figure is an unrealistically large estimate of land cost differentials for a given type of laboratory as between locations. But even at this level, its influence on location decisions cannot be decisive for the large majority of laboratories.

[10] The empirical studies are not directly to the point but, nevertheless, do provide some support for the proposition offered in the text. The thrust of the empirical studies has been with respect to intra-metropolitan composition--large versus small municipalities in a metropolitan area. (Cf., for examples, J.C. Bollens, ed., Exploring the Metropolitan Community (Berkeley, Calif.: University of California Press, 1961) Chapters 14, 15; W.Z. Hirsch, "Expenditure Implications of Metropolitan Growth and Consolidation," Review of Economics and Statistics, August, 1959; H.E. Brazer, City Expenditures in the United States (New York: National Bureau of Economic Research, 1959) pp. 25-28). The proposition that quality relative to cost of community services is independent of size of the local community is in reference to total local urban area size not to fractions thereof. There is good reason to believe that greater variation of service quality and cost exists among the municipalities of large metropolitan areas than between two comparable municipalities in two urban centers of different size. (On viewing municipalities within a given center as offering different packages of public services, see C.M. Tiebout, "A Pure Theory of Local Expenditures," Journal of Political Economy, October, 1956). It is this latter which is of greater significance to us. If a choice is made among urban centers, it is to be expected that the particular sites (and municipalities in which those sites are found) will offer something close to the same set of characteristics including community services.

If empirical studies dealing with cases where differences, by theoretical inference, are considered to be greater cannot establish significant differences, it is submitted that the proposition, referring to the case where lesser differences are to be expected, has merit. If, however, the proposition in the text is wrong and our results should indicate external effects from community services, this would call into challenge the procedures of the study erroneously and our overall results would not involve conclusions that were unjustified. On the other hand, if these external effects do not appear in the item referring to community services, that finding does provide some evidence that a bias is not involved in the procedure of the study.

[11] To cite a few random examples of the voluminous material in support of this point: C. Clark, "The Economic Functions of a City in Relation to its Size," Econometrica, April, 1945, pp. 97-113; P.S. Florence, "Economic Efficiency in the Metropolis," The Metropolis in Modern Life, R. Fisher, editor (Garden City, N.Y.:

Doubleday, 1955), pp. 86-88 ; M.J. Beckmann, "City Hierarchies and the Distribution of City Size," Economic Development and Cultural Change, April, 1958, pp 243-248; I. Morrissett, "The Economic Structure of American Cities," Regional Science Association Papers and Proceedings, 1958, pp. 239-256; H.H. Winsborough, "Variations in Industrial Composition with City Size," Regional Science Association Papers and Proceedings, 1959, pp. 121-131; W. Isard, Location and Space-Economy (New York: Wiley, 1956), pp. 57-59.

[12]Clark, op. cit., p. 113.

[13]R.B. Vance and Sara Smith, "Metropolitan Dominance and Integration," The Urban South, Vance and N. Demerath, editors (Chapel Hill: University of North Carolina Press, 1954), emphasize the distinction between metropolitan areas with a regional focus and those whose orientation is to national or international markets, referring to the latter group as "super" metropolises. The category of such cities is implicit or explicit in the work of many others as well. Cf., for examples, E.J. Taaffe, "The Urban Hierarchy: An Air Passenger Definition," Economic Geography, Jan., 1962, pp. 1-14; O.D. Duncan et al., Metropolis and Region (Baltimore: Johns Hopkins Press, 1960), pp. 264-266.

[14]Cf., Census, p. xxiv. The essential requirement in the Census' SMSA definition is that the central city have a population or that two contiguous cities have a combined population of at least 50,000.

[15]Florence, op. cit.; Duncan, op. cit., p. 271.

[16]Clark, op. cit., p. 112-113.

[17]It also coincides with Duncan's (op. cit., p. 271) classification of "national metropolises."

[18]Vol. I, Part A, Tables 24, 33.

[19]One reason is offered by Ralph E. Lapp, "Where the Brains Are," Fortune, March, 1966, p. 179, in the following observations: "The R and D firms around Boston chose the area for many reasons, but one stands out: scientists like to be near the intellectual hum of Harvard and M.I.T."

[20]Source: Doctorate Production in United States Universities: 1920-1962, op. cit. Geographic locations supplied.

[21](Washington, D.C.: National Academy of Sciences, National Research Council), 11th edition. A 12th edition of this title was published in 1965. Unfortunately, the later edition (which for the first time was not compiled by the National Academy itself) omitted such a large number of laboratories which were known to

exist that it was felt to be unreliable as a representation of the universe of industrial research laboratories. A subsequent check of the 1965 edition against respondent laboratories in the same use in this study showed approximately one-third to have been omitted!

While undoubtedly there are some omissions from the 1960 edition, it appears to be considerably more comprehensive and more representative of the universe of laboratories in the U.S. than the later edition. It would probably be an inappropriate use of the 1960 (or any other) edition of Industrial Research Laboratories to attempt to obtain totals on industrial research in the U.S. by a simple summary of the laboratories recorded. But, after discussions with its editor and further careful consideration, it does not appear that the omissions are seriously biased with respect to location or size of laboratories. The 1960 edition does contain a comparatively small number of laboratories that do not perform research. Since the interest in this study was only in research laboratories, those not performing research were excluded in the selection of the sample and replaced by another randomly selected laboratory. In a negligible number of instances, organizations with more than one laboratory location did not provide information for separate locations. These laboratories were dropped from the sample.

[22] To be scrupulously accurate, 8.8 per cent of the total. However, when the non-research laboratories are omitted, the percentage would be very close to the figure mentioned in the text.

This is a larger sample than would have been necessary for the purpose of this study but other uses were to be made of the data necessitating stratification and proportions. Except for these modifications, the principles of random sampling were followed.

[23] See Statistical Appendix, Sections B and C.

[24] Responses in this intermediate category of neither substantial advantage nor disadvantage constituted 13.25 per cent or less of all save three of the ten items concerning local environment.

[25] Without wishing to place undue emphasis on the point, by ranking the items in Table 1 according to the proportions of total responses indicating a substantial effect by the location, one should obtain a crude estimate of the importance ranking of the items in the view of the laboratory directors. If this is done, the items fall into two well defined groups. Group I with a mean of about 87 per cent includes items 2, 3, 4, 5, 6, 7, 9 which are clustered very tightly together. Group II with a mean of 76 per cent includes only three elements which surprisingly include: supply of professional research personnel and size of market for research and, perhaps, less surprisingly, prestige of region.

[26] National Science Foundation figures show that for 1962, 20.2 per cent of all scientists engaged in research, development, or design in the United States

were employed in the 5 cities of 3 million or more population. In 20 other selected SMSAs (all over 250,000 population) an additional 34.6 per cent were employed. The remaining 45.2 per cent unfortunately were distributed among both SMSAs of varying size and non-metropolitan areas. Nevertheless, these figures do suggest that concentrations of research in the largest cities are generally high. Source: American Scientific Manpower: 1962 (Washington, D.C.: National Science Foundation, 1964) Table 26.

[27] See Note b to Table 2.

[28] See Statistical Appendix, Section D.

[29] Thompson, *op. cit.*

STATISTICAL APPENDIX

Section A: Homogeniety of Sample

The sample of industrial research laboratories used in this study was composed of laboratories owned by industrial companies (comprising some 85 per cent of the total) and independent commercial and non profit laboratories (making up the remaining 14 per cent). These two groups conceivably could demonstrate very different locational patterns. If they did show different locational characteristics relevant to this study, it would be necessary to treat the two groups separately and generalizations would have to be truncated.

To provide reasonable assurance as to the homogeniety or lack of homogeniety of the sample, the two groups were tested with respect to the city size categories and Ph.D. production classes to which their locations belonged in 2 x 3 contingency tables. The results of the tests, neither of which indicated Chi-square values that were even close to significant at the .05 level, are shown below. It was concluded that the two classes are not significantly different and that the sample could be treated as a homogeneous.

Tests for Homogeniety of Sample

I. City Size

	250,000 & Under	250,000 - 3 Million	Over 3 Million	Totals
Industrial Owned or "Captive" Labs	27 (27.62)	125 (123.44)	50 (50.93)	202
Independent Commercial and Non Profits	5 (4.38)	18 (19.56)	9 (8.07)	32
Total	32	143	59	234

2 degrees of freedom

$X^2 = 0.370 \quad .90 > \alpha > .80$

Not Significant

II. Resources to Advanced Training of Scientists

(Ph.D. Production)

	0-10	11-1500	>1500	Totals	
Captive Labs	68 (67.33)	85 (82.01)	49 (52.67)	202	86.2%
Independent Commercial and Non Profits	10 (10.67)	10 (12.99)	12 (8.34)	32	13.8%
Totals	78	95	61	234	

2 degrees of freedom

$X^2 = 2.717 \quad .20 < \alpha < .30$

Not Significant

Section B: Representativeness of Response

The sample referred to in Section A consisted of 475 laboratories of which 234 made responses. Although the sample was selected at random, the responses could easily be unrepresentative of the sample and bias conclusions. If the responses were unrepresentative of the sample it would be necessary to choose a new sample or make qualified conclusions regarding the responses.

To determine the representative of the responses, the two groups (total sample and respondents) were tested with respect to scientific category, geographic area, and city size by means of 2 x 3 contingency tables. None of the resulting Chi-square tests indicated values that were significant at the .05 level. From these tests it can be concluded that the responses were representative of the sample and were unbiased.

Tests for Representativeness of Response

1. By Scientific Category

Cells are in percentages

	L	C	P	N	
Total Sample	9.41 (10.465)	32.84 (33.895)	48.16 (45.64)	9.59 (10.00)	100
Respondents	11.52 (10.465	34.95 (33.895)	43.12 (45.64)	10.41 (10.00)	100
	20.93	67.79	91.28	20.00	200

3 degrees of freedom

$X^2 = 0.59$ $.95 > \alpha > .90$

Not Significant

II. By Geographic Area

	NE	MW	W	S	
Total Sample	51.84 (49.90)	30.26 (31.485)	11.81 (11.48)	6.09 (7.135)	100
Respondents	47.96 (49.90)	32.71 (31.485)	11.15 (11.48)	8.18 (7.135)	100
	99.80	62.97	22.96	14.27	200

3 degrees of freedom

$X^2 = 1.44 \qquad .70 > \alpha > .50$

Not Significant

III. By Different City Sizes

Cells are in percentages

	< 250,000	250,000-3M	> 3M	Total
Respondents	13.68 (13.88)	61.11 (57.97)	25.21 (28.15)	100.00
Total Effective Sample	14.07 (13.88)	54.83 (57.97)	31.09 (28.15)	100.00
Total	27.75	115.95	56.30	200.00

2 degrees of freedom

$X^2 = .960 \qquad .70 > \alpha > .50$

Not Significant

Section C: Appropriateness of Universe from which Sample was Drawn.

The study sample was drawn from the 1960 edition of Industrial Research Laboratories of the United States. Since it is known that a substantial number of laboratories have been located since that date, it is possible that the locational pattern of laboratories has been altered significantly from the pattern which is represented by a sample drawn from a 1960 universe.

Because of limitations of the 1965 edition of Industrial Research Laboratories, a sample could not be selected from this later edition without risking introduction of still other biases. It was reasoned that all laboratories established or relocated since 1960 would have been influenced in the selection of location by approximately the same forces acting upon the laboratories in the sample that had relocated during the same period. Such an assumption probably overstates the differences between the sample laboratories locational pattern and that of new laboratories. Nevertheless, if the laboratories in the sample that have moved can be shown not to demonstrate significant variation in locational pattern from that of the sample, it provides some assurance that the sample offers a reasonable reflection of the locational pattern of industrial research laboratories as of 1965-66.

Chi-square tests were made from 2 x 2 contingency tables between the total sample and laboratories that had moved between 1960 and late 1965 with respect to three randomly selected elements of environment. As shown below the Chi-square values were very small in every case and far from significant. It is concluded that the sample is acceptably representative of the current locational pattern of laboratories.

Tests for Differences in Responses Between Total Respondents and Respondents Whose Laboratories Moved During 1960-65

I. Supply of Professional Research Personnel

	Total	Moved Labs	
Advantage	109 (109)	14 (14)	123
Disadvantage	66 (66)	9 (9)	75
	175	23	198

1 degree of freedom

$X^2 = 0$

Not Significant

II. Supply of Technical Level Personnel

	Total	Moved Labs	
Advantage	166 (165.4)	18 (18.6)	184
Disadvantage	57 (57.6)	7 (6.4)	64
	223	25	248

1 degree of freedom

$X^2 = .087 \qquad .70 < \alpha < .80$

Not Significant

III. Access to Production Facilities

	Total	Moved Labs	
Advantage	178 (176.3)	19 (20.7)	197
Disadvantage	43 (44.7)	7 (5.3)	50
	221	26	247

1 degree of freedom

$X^2 = .622$ $.30 < \alpha < .50$

Not Significant

Section D: The Association of City Size and Ph.D. Production

It is evident that a statistical association exists between the city size categories and the categories of local Ph.D. production used by this study. For informational purposes a Chi-square test was made and the Coefficient of Contingency was computed. (See below.) The Chi-square showed, as expected, that the association would test significant at a high level (.00l). The C value of .540 must be read against the upper limit of C for a 3 x 3 contingency table of .818. Individual contingency coefficients are hard to assign meaning to. But this figure represents a slightly lower level of association than the highest C's obtained between individual elements of the laboratories environment and city size.

I. X^2 Test of Associating Industrial Research Laboratories by City Size and by Local Ph.D. Production

	City Size			
Ph.D. Production	< 250,000	250,000-3M	> 3M	Total
0-10	29 (10.803)	50 (48.278)	0 (19.919)	79
11-1500	1 (12.992)	78 (58.056)	16 (23.953)	95
1501-00	2 (8.205	15 (36.666)	43 (15.128)	60
Total	32	143	59	234

4 degrees of freedom

$X^2 = 140.04 \quad \alpha < .001$

C = .540 with .818 as the upper limit for C in a 3 x 3 table