Symposium on Science and Irish Economic Development

(Held on December 16th, 1966)

Contribution by D. I. D. HOWIE

THE PRODUCTION OF SCIENTIFIC MANPOWER: THE ROLE OF THE UNIVERSITY

None of us, I suppose, would deny the basic assumption that greater efforts in research and technology would strengthen the economy, whether through improved agriculture or improved and diversified industrial output. If we make the further assumption that there will be a decision to invest substantially greater sums, both public and private, in research and development, there arises an important question: how shall we produce the scientific manpower required? If there is one thing on which any programme of technological development must depend, it is skill, both physical and cerebral. What seems certain is that any expansion of our scientific work force will have to come from our own people. There is an existing shortage of trained researchers in Ireland and we would find it difficult to compete on the international market for large numbers of ready-made researchers and technicians. I do not wish to dwell too long upon educational matters not deemed to be within the terms of reference of the O.E.C.D. team. Nevertheless, if we are not to fill our laboratories with low calibre scientists and technicians, improved and expanded scientific education in schools, technical colleges and universities must take priority in any plan for technological development. This is simply because the training of individuals takes longer than the period required to set up equipment and build plant.

The report does provide figures for the annual investment in research in the universities. This, of course, is directly related to the capacity of the universities to train students at the research level and is also related, although less directly, to the degree of sophistication of undergraduate courses. According to the report, the expenditure on research and development in the universities amounts to £394,500. Of this, the amount spent on fundamental research is £84,900. My own estimate is that this latter sum would provide adequately for just one research establishment employing perhaps fifteen graduate staff. It has to be admitted that the authors of the report were at the mercy of the university professors who filled out the questionnaires and who, no doubt, were at pains to show that the

research carried on in their departments was of some national importance. Thus much research labelled "applied" probably should be labelled "fundamental". In addition, I gather that cost of maintenance of laboratories and administration are not included in these figures. For these reasons, the figures given for the annual cost of both fundamental research and total research in higher education, could be underestimated. However, one has to look at the reverse of the coin. The State contribution of £210,000 for research in higher education presumably is mainly comprised of a fraction of staff salaries related to the proportion of man hours spent on research as opposed to teaching. Again, I believe that this proportion was calculated from replies to questionnaires. In Britain, with staff:student ratios varying between two and three times better than ours, the Robbins Report stated that university staffs were only able to devote between 23 per cent and 32 per cent of their time to research. If these figures represent the true position in Britain, it must be assumed that the proportion of staff time and salary in Ireland which can truly be said to be devoted to research must be very small indeed. The point I wish to make here is that while university men and women in Ireland do make the time for research, in fact the contribution of the State to university staff salaries is really insufficient to satisfy the requirements of basic undergraduate teaching and is certainly insufficient to make any real provision for research.

There is one route by which the State aims funds directly at research in the universities. This is through the Department of Education's Training Awards which provide maintenance for graduate students in science and engineering. This fund is still small, but is rapidly increasing and has reached £22,000 this year. It is, however, of particular relevance to the training of scientific manpower and I would like to stress its value in this respect. This scheme, or something similar, must expand both in terms of the value of the awards and the numbers of disciplines which it covers, along with any plans for scientific and technological development.

While discussing the present scale of operations, attention should be drawn, as indeed it is in the O.E.C.D. report, to the very significant proportion (above 33%) of research expenditure in the universities earned from abroad and from private sources. I use the word "earned" advisedly in this context. In Trinity College in 1964–65 current research funds, expendable over a two or three year period, amounted to approximately a quarter of a million pounds from private sources and from abroad. These funds were collected for some 64 projects and no less than 62 fund sources had to be approached to raise this sum. No one among my colleagues objects to the work entailed. It is a fact of life in university research, not only here, but also in Britain and America. There is, however, an important difference. In most institutions in these countries, funds obtained other than from the State provide the gilt on the gingerbread. In Ireland, with the low total expenditure on research, they provide the bread and butter. There are, of course, two dangers involved in our degree of dependence upon funds "from outside sources". First of all, there is the danger that too much staff time is spent simply on earning the money and that research may become too "orientated". A second, and more important danger

perhaps, is that international sources of funds are insecure, especially in a time when international balance of payments difficulties are increasing.

There is no point simply in complaining in a subjective way about the low level of research expenditure in the universities. Fortunately the O.E.C.D. report supplies us with some objective criteria which can be applied. By the only objective test of productivity we have, i.e. output of papers per head, the universities match all other research institutions in the country at a cost per graduate substantially less than half that of any other institutions. Admittedly there are restrictions on publication in some institutions, and a man employed strictly on applied research may take longer to produce a result than in the case of one who can follow any promising line. Nevertheless, for the same price, the universities train the new generation of researchers. In fact, Ireland is getting its researchers very cheaply.

I have mentioned the adverse staff:student ratios in the universities. Despite this, in our most recent survey in Trinity, we discovered that on average each full-time member of staff in the science departments manages to supervise 1·7 graduate students. This compares with the national average of 1:1·3 in the British universities at the time of the Robbins Report. I think we have reason to be proud of this effort. Of course, the absolute number of graduate students in Ireland is relatively small because this is related to the number of staff available to supervise them. Thus in Great Britain back in 1962, 14 per cent of all students in universities were graduate students, while last year in Trinity, the figure was only 7·5 per cent.

This would seem to be an appropriate point at which to leave figures aside. I have tried to show that the universities are at the moment reasonably efficient and productive within present financial limitations in their dual role of turning out researchers and actually producing research. This brings me back to the point at which I started out, namely the priority which must be given to boosting our educational machinery and processing people through it. The aim must be to raise the number and proportion of students I have just mentioned, who reach the stage of receiving research training. It seems clear that the proposed Advisory National Science Council will have to devise a research programme which takes into account the flow of graduates and technicians. In the absence of a decision to spend larger sums on higher education and the research which goes with it, the recommendations of the O.E.C.D. team relating to the formation of a National Science Council and formulation of a national research programme must, to a large extent, lose any relevance. The bill for education will be a heavy one. Not only will the schools and universities have to accommodate more students, and so require more laboratories and equipment, but we shall have to have substantial staff increases, not only because of the greater student numbers, but also to increase the sophistication of courses by introducing more specialities. The chief recommendations contained in the O.E.C.D. report, if adopted, would not have much direct influence on research in the universities except, for instance, that the colleges may be stimulated to pursue research upon natural resources.

Nevertheless, one must have reservations with regard to some of the proposals. It is plainly desirable to set up a National Science Council with the aim of formulating a cohesive research policy. However, the organisation proposed is too large in relation to the small size of our total scientific effort. Its complexity would also seem to militate against rapid policy decisions. Of more interest to the universities is the emphasis in the report upon the need for concentration of our research resources in large institutes. The point is made, with some cogency, that many university departments are too small and poorly financed to be effective research units. In fact, most of them would be perfectly viable if numbers of students were recognised by provision of an appropriate number of staff. The report makes the case for a single institute for research in the higher education sector. This, I am sure, would be rejected by the vast majority of university people. It would undoubtedly mean the segregation of staff into those engaged in research and second class citizens engaged upon teaching solely in the colleges. Undergraduate teaching would be impoverished and the universities reduced to the status of liberal arts colleges. This situation would scarcely fulfil the aim of turning out a skilled scientific work force. I am sure that the colleges, including Trinity, would rather face the alternatives which will be hard decisions upon the distribution of more expensive items of equipment and facilities.

There is a final and perhaps even thornier problem. During the period of expansion of the major research institutes and presumably coincident expansion of the university sector, there is likely to be severe competition for high quality staff. It would be my own view that much closer links must be evolved between the institutes and the colleges so that this nucleus of skilled people not only participate in the national research programme, but also contribute to the education of the new generation of scientists.

Contribution by T. E. NEVIN

This survey is a mine of information but I do not feel that this is the occasion for commenting on points of detail. I propose to confine myself to some observations on matters of general principle, particularly concerning myself with those parts of the report which concern the universities and fundamental research.

That a National Science Policy is needed goes without saying. There are, however, aspects of science policy other than those dealt with in the report. There is the continuing need to give a more scientific and mathematical content to the courses in secondary and vocational schools but here our aim must be at least as much educational as utilitarian. That we are making progress is shown by the fact that in the present session 226 out of 246 students, 92 per cent, entering the science faculty in U.C.D. had taken a science subject in Leaving Certificate compared with 99 out of 132 students, 75 per cent, in 1957–58.

How many graduates in pure and applied science do we need? Can we persuade the ablest of our young people to embark on the kind of careers

needed or more precisely, the kind of careers we think we need. Will they be willing to remain in Ireland after graduating? When one considers the immense effort being made in Great Britain to increase the number of engineering graduates from the universities and to raise the status of the engineering profession, we must consider ourselves fortunate that in Ireland as in most European countries the great majority of our engineers are university graduates and the profession enjoys esteem, if not yet the influence on affairs it should have. If in estimating requirements of future graduates in various fields, a mistake or an error of judgment is made, it takes a long time to put things right.

Everyone who has given thought to the matter must endorse the idea of a Science Policy Committee but I wonder if the proposed body may not be too large in size. Everyone knows that the appointment of a large body is effectively a recipe for doing nothing or for doing something very slowly. That members should be appointed as individuals and not in a representative capacity is an excellent idea. Likewise, the proposals about the scientific qualifications of the secretariat are sound.

Considering the financial needs of fundamental research, pure and oriented, and long-term applied research, I feel very strongly that in addition to funds drawn from the general grant in aid, the universities should, as is the case in many other countries, have a second source available of funds for research. This second source might be administered by a National Science Foundation operating under the Science Policy Committee. Funds might be administered with the aid of specialist advisory panels including a proportion of foreign scientists.

There are innumerable references throughout the report to what is called interdisciplinary research and to interdisciplinary teams but nowhere that I can find did the team spell out what they meant by this. Related to this is a reference to rigid compartmentalisation of Irish universities. Do they mean by this for example, that the main research effort of a physics department should not be in physics? While it is true that with maximum publicity a small number of the new universities in Great Britain are experimenting in new forms of organisation, the vast bulk of the universities throughout the world, including the U.S.A., are organised as in Ireland. The strait-jacket in which the Irish universities are bound is lack of money and this is the main source of any apparent rigidity. In so far as flexibility exists in the United States, it is the flexibility made possible by practically unlimited amounts of money. According to a table on page 227 of Volume 2, 45·5 per cent of technical personnel in Ireland graduated from University College, Dublin, the other three universities between them supplying 36 per cent. I do not know whether it is realised that in University College, Dublin, the income per full-time student, outside Veterinary Medicine and third and fourth year Agriculture, from all sources including fees is £190 which is less than the amount available for a full-time day-student in a Dublin Vocational School. Moreover, since about 1959, the College has had to find from its annual State grant-in-aid about £400,000 for temporary accommodation over and above special sums for this purpose provided by the State.

If it seemed desirable or necessary, there would be no difficulty in providing courses leading to two subject honours degrees in physics and geology or physics and biochemistry or applied physics or applied chemistry. By and large, Irish industry operates at such a low level of scientific competence that I doubt whether many firms know enough to formulate their real long-term needs. Certainly they never make their needs known to the universities. The absence from the report of any detailed reference to nuclear energy is quite astonishing. Those of us who involved ourselves in the subject ten years ago were acutely aware that the bringing together of pure and applied scientists would be not the least of the advantages which would result from the provision of a research reactor.

At the postgraduate level, fundamental research depends on the interests and ideas of the individuals concerned. To start work in a field like biophysics or molecular biology, requires a scientist of high ability with adequate finance and back-up in the way of accommodation, equipment, technicians, finance and research students. Individuals of the calibre required are relatively rare and cannot be produced to order.

Strong departments of the basic sciences with academic staffs, in addition to their teaching, actively engaged on research are essential to the scientific life of the nation. Teaching and research are intimately linked together and constant attention is necessary to maintain equilibrium between them. This is the theme of all international reports on fundamental science. The Seaborg Report of 1960 to the President of the United States recommended "It should be a general basis of policy and action that basic research and the education of scientists go best together; that they are inseparable functions of universities." The General Assembly of European Rectors and Vice-Chancellors meeting at Gottingen in September 1964, with representatives from nearly every university in Europe, including these islands, recommended "It remains a basic necessity for every institution of university standing to be in a position to ensure that there is a close and real link between teaching and research at all stages of the student's education." The paper "Fundamental Research and the Policies of Government" prepared by O.E.C.D. for the meeting of Ministers of Science in January 1966, a paper which every administrator concerned with policy making should be required to read, states, "It is a basic contention of this report that fundamental research and the processes of higher education reinforce each other in a variety of ways and each is substantially weakened if not fed by the other". The suggestion therefore that all university research should be concentrated in a single science centre is one which, if carried into effect, would destroy the science and engineering faculties of the universities. It is noteworthy that United States industry prefers to recruit scientists at the Ph.D. level who have had three or four years experience of pure research. U.S. industrialists know by experience that men of this type will keep in touch with the evolution of their subject and will be effective in dealing with a whole range of problems, bearing no relation to the subject of their original research.

The report we are discussing places much emphasis on team work and perhaps it is necessary to say that original ideas and new discoveries come from individuals, not from teams—frequently in quite unexpected ways and from unexpected directions. Fundamental advances cannot be planned in advance. Quite frequently, the new idea and its initial testing and development have been reasonably simple. A classic example from 1939 was the discovery of nuclear fission. It is the further stage of exploitation and use which requires a massive deployment of resources. It is usually said that Glaser got the idea of the bubble chamber, now one of the main tools of elementary particle physics, by looking at bubbles forming in a bottle of beer. Whether or not this is true, Glaser's original bubble chamber for which he received the Nobel prize is far removed from the vast instruments now in use with hundreds of litres of liquid hydrogen and magnets weighing hundreds of tons so complicated that they must be programmed by on line computers. Mossbauer's discovery of recoilless emission of gamma rays and the studies of optical pumping for which Kastler received the Nobel prize this year, were also simple.

Looking at the general picture of research, I think the universities come extraordinarily well out of this survey. Bearing in mind the teaching load, the time needed to keep teaching up to date and the poor student/staff ratio which in U.C.D., for example, is 22/1, the volume of original research from the universities virtually all published in international journals with a strict refereeing system is very creditable. The simple facts are that as the survey demonstrates, the universities are seriously understaffed, that there are grave deficiencies in technical staffing, that the amount of money available is by any standard hopelessly inadequate but in spite of this, the bulk of published scientific work comes from the universities.

Since in the words of the Trend Report "Science in the Universities is the ultimate foundation on which all scientific effort rests", it is worth pointing out that our primary degrees are of good international standard. The Committee of Higher Education of the Council of Europe is engaged on a study of the equivalence of degrees in European universities. The chemistry survey has been completed and published. I myself, three weeks ago, presided at a meeting in Strasbourg on equivalence in Physics and a report will be published in the spring. Work on other scientific and socio-economic subjects is in progress. I feel I can say without hesitation that whatever problems we may encounter when we go into the Common Market, the standard of our science degrees will not be one of them.

Many minor deficiencies and errors would have been avoided if an academic scientist associated with teaching and research had been associated with this survey. This brings me to another point for the future—the need to involve scientists and engineers in policy and decision making. The post-war history of the United States in particular, where scientists are directly involved in all decisions even at the highest levels is proof of the value of this. While they may help in formulating it, economists cannot direct science policy. Scientists and technologists will not accept a situation in which economists and administrators make decisions on

ends and means and a scientific elite is expected obediently to carry out their masters' decisions. You must carry the scientific community with you. The brutal fact is that we compete in an international market for scientists and technologists, particularly those of the highest abilities, and unless the proper environment is provided, the ablest and most experienced of our younger scientists and engineers, those capable of independent thought, will go abroad.

Lest I appear as just another unpractical scientist, I ought to say a few words on the universities and applied research. I have no doubt that in existing circumstances suitable university departments should undertake some applied research of wide scope and basic importance. To do this effectively might require the creation of sections inside existing departments or even new departments endowed or partly endowed by industry. The Chair of Industrial Microbiology in University College, Dublin, endowed by Messrs. Guinness and Bord na Mona provides an example. I might add that such chairs might well be established in Cork and Galway and might help greatly in the problem of viability.

Opportunities should be provided to enable industrial scientists to spend a Sabbatical period in a university working in conjunction with or under the supervision of members of the university staffs. This would be mutually stimulating, giving industrial scientists an opportunity to refresh and to widen their knowledge and acquainting university staffs with problems of Irish industry. Possibly too, industrial scientists, on leave of absence, could help in the training of young research workers, directing their attention and interest to Irish problems and conditions. It is perhaps worth pointing out that under existing regulations, graduates of the N.U.I. who have spent a total of twelve terms in a particular college, may submit for a Ph.D. degree work done elsewhere under the general direction of the professor. This regulation would, for example, permit a scientist working in industry to submit for a Ph.D. degree work done in his own laboratory on a suitable industrial research project. Lastly, Irish industrialists should establish contacts with the universities and with students, particularly in their final year and explain to them the kind of careers in and the problems of Irish industry. Up to the present, these contacts have been lamentably few and the fault does not lie with the university professors.

Contribution by A. V. VINCENT

As an introduction to my paper this evening I shall give a brief resumé of the scientific research undertaken by Arthur Guinness, Son & Co. Ltd. at St. James's Gate. It has a long history and for a full understanding of the role played by scientists in the brewery, we must go back to the end of the last century. The world's largest brewer, having devoted his energies for almost 100 years to increasing production, started in 1893 to recruit graduates recently qualified in chemistry, not only as chemists but as brewers. During the following decade a research programme slowly

crystallised and the first few years of this century saw the formation of the Guinness Research Laboratory and the building of two important pieces of experimental plant—a malthouse in 1901 and an experimental brewery in 1903. Both were what would now be called large pilot scale copies of industrial plant—indeed they were then larger than some commercial units.

About that time the Department of Agriculture was formed, and in 1901 embarked on a programme for improvement of the barley crop. We as the major consumer were immediately involved. The total requirements of barley for the manufacture of the malt and roast material used by Arthur Guinness, Son & Co. Ltd. are purchased in Ireland. Over £2 million is paid to 16,000 Irish farmers for the 75,000 to 80,000 tons of malting barley we require. As this represents a large portion of the total malting barley crop we are in a unique position with regard to barley growing and play a leading part in the researches which are carried out. The liaison between the Department and ourselves has been of considerable value to all growers of malting barley, maltsters and brewers in Ireland.

In 1901 a national survey of the different varieties which were then being grown was carried out; these included Chevalier, Archer, Goldthorpe and Standwell although most barley was very mixed. That year saw the introduction of variety assessment trials in the principal growing areas, a practice which has continued to the present day. The year 1907 may be taken as completing the first phase of Irish barley research concerned with testing Archer, Goldthorpe and Standwell; the main interest began then to shift to hybrids. The first hybrids bred in Ireland had been crossed in 1905, initially between those varieties which had proved themselves under Irish conditions. Then in 1908 Archer was crossed with a variety Spratt, grown only near Ely in Cambridgeshire. Selections from this cross formed the major part of the Irish crop for over 30 years.

Apart from a break at the time of the 1914–18 war, breeding and testing of new strains continued but no variety supplanted Spratt–Archer until it was crossed with a Continental variety, Kenia, and produced a stronger and earlier ripening strain given the name Beorna. This is an interesting variety as, not beingg enetically pure, it produces, within the crop, plants of varying height and appearance. Beorna is very susceptible to lodging and further selection of the same Spratt–Archer × Kenia cross gave a stronger strawed and higher yielding strain named Hunter which now forms two-thirds of the national crop. Beorna is still recognised as an outstanding barley from the malting point of view and work continues to find a selection with the same malting quality and improved agronomic characteristics. Intensive research is still being carried out at the Department of Agriculture Cereal Station at Ballinacurra towards developing improves strains of malting barley. Since our work began the yield of the national crop has increased by over 40 per cent but it is recognised that further gains are feasible and we are making every effort to insure the trend remains upward. Especial emphasis is now placed on breeding disease resistant strains and it was hoped that investigation of varieties

grown overseas would produce useful results. However, several years of trials have shown that the varieties developed here are better suited to Irish conditions.

We have worked closely with the Agricultural Institute since it was founded in 1958. A jointly planned series of experiments have been carried out with the aim of improving the quality, yield and cultivation methods of malting barley and a comprehensive survey of malting barley growing is in progress—particular attention is paid to those diseases affecting barley grown in Ireland.

I should emphasise that our relationship with the Department of Agriculture and the Agricultural Institute is not just a financial arrangement. Our staff includes a number of experts in these fields who play a large part in the planning and interpretation of the trials, whilst the laboratory carries out analyses on thousands of barley samples each year.

But we are not only concerned with barley breeding. Other research projects are handled by our laboratories and a Production Research Unit. The work of the research laboratory covers all aspects of brewing and includes much fundamental research. There are about 20 well qualified chemists doing this work and they are available to assist in solving specific brewing problems. The presence in the brewery of such experts is an invaluable asset. The Production Research Unit is primarily concerned with the commercial application of new techniques and is an essential part of a progressive organisation investing in scientific research.

I should now like to add a few words relating to the recent report "Science and Irish Economic Development".

I am a statistician—the head of one of the two Statistics Departments in the Republic of Ireland who are mainly concerned with scientific research. The other is a section of the Agricultural Institute, primarily concerned with the design and analysis of trials in animal husbandry and cereal research. As a statistician, I was gratified to read in the Research and Technological Survey team's report of concern at the shortage of statistical and other support services. To quote from the report:

"Worthwhile research and development is impossible without an adequate level of support services and their importance cannot be over-emphasised."

However, I am sorry that the report contains no recommendations regarding the improvement of the flow of trained statisticians from universities nor is there any discussion as to how support services could be provided to manufacturing companies of small–medium net output. The supply of qualified statisticians from the universities is at present insufficient to fill the vacancies regularly occurring in the few organisations employing statisticians and recruitment is often from abroad. The reason for the general apathy in this field is not clear. Several appeals to the universities for increased emphasis on the practical applications of mathematics have not resulted in any increase in the number of suitable graduates, nor, as far as I know, has there been any call from the students for such courses. This is in spite of the considerable amount of publicity given to the excellent opportunities for graduates in these fields. I regard

the formation of other statistical units as essential if activity in scientific research is to be increased. They will certainly be required at the universities where they should provide a three-fold function—teaching, research, and in an advisory capacity to researchers in other departments. I would like to see a strong section at the Institute of Industrial Research and Standards, not only to assist in the design and analysis of trials and experiments but also to be able to advise industrial concerns in quality control methods.

It was a brewer at Guinness—W. S. Gosset who, working in Dublin at the beginning of this century, established the statistical techniques for the examination of experimental data when only a limited sample is available, and in so doing, extended the range of statistical enquiry to include virtually all agricultural and industrial experiments. We at Arthur Guinness Son & Co. Ltd. have continued the tradition and a statistical approach is used whenever an experiment is considered. It is regrettable that there are so few practitioners in this country and this branch of science should not be neglected any longer.

I should not leave this subject without making some reference to computer and associated technologies. There are several computer installations in the State but virtually all are used exclusively for commercial accounting. Three small machines at the universities are not used extensively for research and reasons for this may be found in the section on Higher Education Research contained in the report. It is also noteworthy that training in scientific computer languages, e.g. Fortran, is not readily available in Ireland. A greater awareness of computer potential in the scientific field is necessary, but I admit it is not easy to see how the problem should be tackled. My own feelings are that the country needs at least one computer larger and faster than those now at the universities or the Agricultural Institute which should be reserved for scientific, economic and market research applications. The staffing should be adequate to undertake instruction in programming, demonstrations of the use of computers in research, and the production of programmes for researchers and industrial concerns. A centre devoted to statistics and operational research with a computer could be envisaged at one of the universities, but I would prefer not to see it tied to academic research and we must ensure that its resources are readily available to industry. I believe that such an organisation could play an extremely useful research role and by letting computing time to manufacturers some if not all the fairly high capital expenditure could be recouped.

To summarise—a statistical approach is essential to all scientific research programmes and more graduates are urgently required. Furthermore the proposed National Science Council should examine the current use of computer for scientific work and ensure that future requirements can be met, possibly by the provision of one or more computer centres.

DISCUSSION

Dr. M. D. McCarthy said that he wanted to join in the tribute paid to the work of the team on this project and to express his appreciation of the

very large amount of hitherto unavailable material they produced. Despite this he felt bound to say that he did not consider that the organisation of the project was really appropriate for the tasks it had to perform. The ' Investment in Education ' project was in his view much more successful, in that the team had to provide a factual statistitical background on which policy decisions could be based. In the present case the team was expected to go further and to recommend policy measures. This he did not think worked out as well as in the earlier case and, in effect, prejudged to a fairly considerable degree the policy issues and gave undue weight to the particular point of view of a very limited number of people in any subsequent discussions.

The statistical material in the report provided the first information available on a very important field but he wished to express his doubts as to the quality of some of the statistics. In a well documented field it would be possible to cross check the final figures. In this case all one could do was to check certain minor items which data were otherwise available and on such tests he had found a number of minor but very disturbing errors which raised doubts as to the general quality in the material.

He would fully agree that graduate, or indeed undergraduate, training in universities could not be divorced from research and he would therefore be opposed to any suggestion that all university research should be concentrated in a single institution. This was not to say that we could rationally envisage the provision of postgraduate schools in each of, say, twenty scientific disciplines (including the social sciences) at each of our four university institutions. He believed that the one most important element in the development of research activity was the provision of proper postgraduate training co-operatively and rationally between the different university colleges. This would mean that we simply could not put postgraduate schools in all subjects in all the colleges. This was a problem of the rational utilisation of resources and could only be solved in a reasonable way by treating it from the point of view of the country as a whole and not from that of any individual institution.

He also wished to stress the difficulties in the way of the economic evaluation of research projects. It had become fashionable to talk about the value of methods of cost-benefit analysis. This was a very useful tool but it was well to recognise limitations. It was particularly appropriate while considering alternative solutions to a particular problem in a relatively narrow field. One could usually assess the costs of such alternative proposals reasonably comparably. The evaluation of the benefits depended to a considerable extent on conventional decisions about pricing. The effect of such conventional decisions in a fairly narrow field could be relatively unimportant but the same was not true when the types of benefit envisaged diverged widely. In many cases there was considerable doubts as to whether one could set a value on such benefits at all. When the field of decision was very wide and the types of benefit very different then the levels of evaluation could have a very serious impact on the material provided for the decision makers. This meant that the methods of cost-

benefit were considerably less easily applied in, say, the evaluation of investment policies across such different fields as health, education etc. This, of course, was not to say that one should not try to quantify both cost and benefit. It was merely to recognise the limitations of the method and to suggest that the problem of its application in the field of the Report under review raised very considerable difficulties.