# *An Approach to National Manpower-Planning in Science and Technology*

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ABSTRACT

Data from the 1971 Census relating to the stock of graduates having degrees in science and technology has been associated with the data on expenditure on research and development, expenditure on higher education and measures of sectoral economic activity, to form a basis for a national manpower planning model with potential use as a decision aid. It is suggested that there is need for making available reorientation procedures for graduates with specialist degrees in the natural sciences, who are being produced in considerable surplus.

## INTRODUCTION

This paper outlines a method of approach whereby the hitherto assumed relationship between science, technology and economic development may be examined quantitatively, as an aid in the determination of State policy.

Interest in this relationship began to be expressed significantly by the State at the time of publication of the OECD Report 'Science and Irish Economics Development' (Stationery Office, 1966). This report was discussed at a symposium in the Statistical and Social Inquiry Society in November 1966 to which D.I.D. Howie, T.E. Nevin and A.V. Vincent gave prepared contributions. The stress in all these contributions was on the need for stronger links between the universities and industry, if investment in research and development (R&D) is to be productive. The essential connection between research and third-level teaching was also stressed.

Behind the OECD Report and the ensuing discussion lay an implicit model consisting of a flow of trained technologists, their appetites for industrial problem-solving whetted by a spell of training associated with relevant R & D, emerging from the third-level system into the industrial system, transforming the latter by creative innovation. It is this implicit model that we propose to try to quantify.

The first outcome of the OECD Report was the setting up of the National Science Council (NSC) in December 1967. For the purpose of this study, the relevant actions of the NSC were (a) the publication in 1967,'69 and'71 of the series 'Research and Development in Ireland' (RDI) by Dr. Diarmuid Murphy (b) the influencing of the Census of Population Division of the Central Statistics Office towards introducing a question into the 1971 Census form relating to qualifications in science and technology (S & T).

By the summer of 1972 the NSC was involved in helping the Census staff with the processing of the completed forms containing S & T responses. The problem of how best to use the emerging data posed itself.

At about the same time the Industrial Development Authority (IDA) produced Part 1 of its Regional Industrial Plans 1973-77. This contained a lot of relevant economic and social data, but little or nothing on the question of technologically trained manpower. The IDA was consciously beginning to develop a policy of upgrading the quality of the jobs generated by their activities, and was aware of this gap in the manpower planning area. There was therefore a positive response from the IDA to a request for support for the development of some quantitative methodology linking up R & D, industrial output, the third-level education system and the existing S & T graduate stock as revealed by the Census for the first time. The system described in this paper is the result.

There is a mass of literature available on 'manpower planning models' in the abstract. Typical is an article in Management Science, Vol 18 no 12, August 1972, by Warren Balinsky and Arnold Reisman, which describes a multi-level dynamic-programming system having a capability for optimising the combined educational and manpower inventory costs. Anyone wishing to explore this field academically will find here a rich set of references. This we did not do, as the problem (as we saw it) lay in the adaptation of a few elementary elements of a model to the data-structure as it was available to us, rather than to find inputs worthy of a sophisticated model taken from the academic literature.

An example of the potential utility of manpower models, in an area where there is good data available, is a book *Qualified Manpower and Economic Performance* published in 1971 (Allen Lane the Penguin Press) reporting some research by a project team (P.R.G. Layard, J.D. Sargan, M.E. Ager and D.J. Jones) of the London School of Economics Higher Education Research Unit. This uses data gathered from the electrical industry and is aimed at the determation of the 'right educational structure' for the labour force, measuring a 'productivity' for qualified people. This is a micro-economic study, taking the factory as unit; by analysis of questionnaire material it establishes distributed measures of economically important parameters.

To summarise:

1. the Balinsky-Reisman model may be described as multi-level, single discipline, single sector, deterministic, optimising, theoretical;
2. the LSE model may be described as multi-level, single-discipline, single sector, probabilistic, optimising, pragmatic;
3. the present model is single-level, multi-discipline, multi-sector, deterministic, non-optimising, pragmatic.

Because of the way in which the structure of the present model was dominated by the availability and structure of the data (i.e. the degree of pragmatism) we felt that it was more important to press on with the work than to spend time searching the literature. The above represents a token recognition of the existence of a body of established methodology in this field; if as a result of this preliminary work some centre of continuity is set up, then it will become possible to make more effective use of the available international experience. To attempt to do so would be beyond the scope of this paper.

The rest of this paper is divided into sections, as follows. First we describe the data sources, and how they influenced our aggregation decisions. Then we show how, using 1971 Census data, we were able to construct an estimate for the 1967 stock, and how we established some measures of trends for the period 1967-71.

We then go on to describe a projection system which makes use of the data and the trends as established in the period 1967-71 to estimate the supply and demand position in 1975 and 1979, on a flexible set of assumptions. We carry out four projections, on three sets of growth assumptions supplemented by one 'changed R & D policy' set of assumptions, as an illustration of the possibilities presented by the use of computer techniques in this field. We then finally present some conclusions, suggested some mechanisms for stimulating demand for graduates in disciplines which are in surplus.

## DATA SOURCES

If the census were the only data-source, it would be possible to group the 342 industrial codes in any way we liked, likewise the 99 possible qualifications codes. However because the RDI studies already existed and had done some aggregation,it was decided to accept twenty-three industrial groupings, defined in the latter and listed in Table I, and the following four broad groupings of disciplines: agriculture (including vets), engineering, medical (including dentistry) and natural sciences. Although social sciences were included in the RDI studies, and we would have liked to include them, they were not included in the census material.

We therefore worked with a 25 x 4 array of sectors and disciplines, the 25th sector being the special one of which the product is manpower. We kept the 24th sector as a spare.

In order to reduce the census material to the form of a 25 x 4 x 11 stock array (we used eleven four-year age-groupings covering the range 20 to 64) we developed a pre-processor which the staff of the Census of Population Division of the CSO ran for us on the State computer at Kilmainham. (We are indebted to them for this service). This pre-processor is flexibly designed and can accept any aggregation rules within wide constraints; it can run also on a regional basis if desired.

### TABLE I

### LIST OF SECTORS

| Sectors | |
|---|---|
| 1 | Central and Local Government |
| 2 | Agriculture and Associated Trade |
| 3 | Building and Construction (excluding electrical contracting) |
| 4 | Transport and Storage |
| 5 | Radio & Telecommunication |
| 6 | Health Services |
| 7 | State Planning & Research Bodies |
| 8 | Development Areas and Physical Planning |
| 9 | Miscellaneous financial, commercial and other services |
| 10 | Education other than 3rd level schools giving degrees in technology |
| 11 | Mining and Peat |
| 12 | Electrical Industry and Associated Commerce |
| 13 | Chemicals, Rubber, Plastic |
| 14 | Vehicle Production and Repair |
| 15 | Metal Products |
| 16 | Machinery |
| 17 | Textiles, Clothing, Footwear and Associated Commerce |
| 18 | Food, Drink, Tobacco |
| 19 | Wood, and Furniture |
| 20 | Paper, Printing |
| 21 | Glass, Clay, Cement |
| 22 | Utilities |
| 23 | Other Miscellaneous industries |
| 24 | Spare |
| 25 | Universities and Colleges of Technology |

Similarly, the RDI aggregation of qualifications into broad disciplinary groups determined the structure of the data provided by the Higher Education Authority. This was prepared by the HEA staff; we are indebted to Mr. John L. Hayden for the graduate statistics (Table V).

The estimation of the breakdown of the cost data over the disciplines (Table VI) is our own (with the help of Rory Alkin, M.Sc., and HEA sources) and we are conscious of its crudity, in the absence of standard budgeting procedures on the part of the various colleges. Absolute measures of unit-costs by discipline are therefore to be taken *cum grano salis,* until such time as good data are available derived from improved HEA statistical procedures. However in the projection procedures we can normalise the graduate output to match the observed numerical situation in the unit-ratios, so that to have correct absolute unit-costs would be an added luxury, not essential to the argument.

As regards the economic background, the measures relating to the 23 industrial sectors were prepared by the Planning Division of the IDA in accordance with our instruction that they should be representative of total output (or total cost, if the sector is a State service) rather than value added. We made this point because we are convinced that to restrict the measure to value added and ignore value of raw material would be to deny the importance of employing S & T manpower in the important field of quality control of industrial inputs. A firm processing high-value material and adding little value to it (e.g. a milk processing factory) is obliged to expend considerable S & T effort in input quality control.

It is not the function of this paper to argue the authenticity or otherwise of the measures of economic activity provided by the IDA. Suffice it to say that we have accepted these measures as a working hypothesis; the function of the system described here is to take these data sets (some more hypothetical than others) and fold them into an integrated information-processing system which will compute measures of their consequences.

The Census head-count for 1971 is given in Table II (1-5). Note that this is not exactly comparable to the figures published by the Census of Population (Bulletin No. 40); thus of the 5,746 gainfully occupied engineers we have got only 5,518 due largely to exclusion of the under 20s and over 64s.

The volumes of gross output, as supplied by the IDA, are given by sector in Table III, along with the graduates employed. An astute reader will ask at this point how were the 1967 graduates employed determined. This is outlined in the next section.

The expenditures and manpowers in graduate equivalents associated with industrial R & D activities, as given in RDI, are displayed in Table IV. Where Dr. Murphy's categories have been aggregated we have brought out the original values, for ease of reference back.

The data as the higher education system, both from RDI and from HEA, are given in Tables V and VI.

## THE BASE-PERIOD 1967-71

In this section we describe how we constructed an estimated graduate stock for 1967, without access to actual census data in that year. We then go on to outline how we determined the trends in the various ratios of interest; we also outline a procedure for taking care of 'wild' trends which derive from statistical fluctuations of small numbers.

In Table VII we display (for an example) the 1971 age-distribution for engineers working in utilities; we display beside it to the left the corresponding age distribution for the same stock as it was in 1967, and to the right of it the age distribution for the same stock as it will be in 1975. These we obtain by displacing the distribution one step upwards and downwards respectively, and operating on it respectively with inverse and straight survival factors. These latter are also displayed.

## TABLE II (1)

## 1971 GRADUATE-COUNT BY DISCIPLINE BY SECTOR BY AGE-GROUP OF THE PRINCIPAL SECTORS

## AGRICULTURAL SCIENTISTS

| Sector | 20-23 | 24-27 | 28-31 | 32-35 | 36-39 | 40-43 | 44-47 | 48-51 | 52-55 | 56-69 | 60-63 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 25 | 139 | 149 | 175 | 115 | 91 | 131 | 121 | 89 | 55 | 35 | 1125 |
| 2 | 25 | 72 | 60 | 49 | 50 | 36 | 34 | 23 | 24 | 21 | 13 | 407 |
| 7 | 3 | 111 | 22 | 36 | 28 | 15 | 16 | 11 | 4 | 4 | 0 | 150 |
| 9 | 19 | 88 | 91 | 107 | 85 | 90 | 61 | 67 | 34 | 16 | 15 | 673 |
| 10 | 17 | 60 | 39 | 27 | 21 | 11 | 16 | 10 | 11 | 8 | 11 | 231 |
| 18 | 42 | 119 | 90 | 119 | 83 | 57 | 73 | 60 | 50 | 28 | 21 | 742 |
| 25 | 6 | 15 | 16 | 25 | 12 | 11 | 9 | 7 | 8 | 4 | 3 | 116 |
| Other | 3 | 18 | 19 | 21 | 20 | 12 | 11 | 20 | 11 | 5 | 0 | 140 |
| TOTAL | 140 | 522 | 486 | 559 | 414 | 323 | 351 | 319 | 231 | 141 | 98 | 3584 |

TABLE II (2)

1971 GRADUATE - COUNT BY DISCIPLINE BY SECTOR BY AGE-GROUP OF THE PRINCIPAL SECTORS

ENGINEERS

| Sector | 20-23 | 24-27 | 28-31 | 32-35 | 36-39 | 40-43 | 44-47 | 48-51 | 52-55 | 56-69 | 60-63 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | 25 | 37 | 50 | 62 | 56 | 72 | 69 | 61 | 47 | 32 | 518 |
| 3 | 49 | 138 | 92 | 108 | 157 | 133 | 141 | 159 | 104 | 57 | 40 | 1178 |
| 4 | 13 | 24 | 28 | 31 | 27 | 28 | 17 | 5 | 7 | 10 | 6 | 206 |
| 5 | 6 | 26 | 18 | 21 | 17 | 12 | 8 | 3 | 4 | 7 | 5 | 127 |
| 7 | 1 | 10 | 15 | 22 | 23 | 15 | 3 | 3 | 1 | 3 | 3 | 99 |
| 9 | 40 | 178 | 128 | 192 | 182 | 131 | 117 | 87 | 79 | 42 | 44 | 1220 |
| 10 | 4 | 18 | 21 | 27 | 17 | 15 | 5 | 3 | 8 | 2 | 8 | 128 |
| 11 | 7 | 14 | 8 | 11 | 10 | 16 | 9 | 19 | 11 | 8 | 3 | 116 |
| 12 | 8 | 48 | 33 | 41 | 24 | 17 | 23 | 13 | 10 | 5 | 10 | 232 |
| 13 | 6 | 25 | 29 | 36 | 27 | 21 | 22 | 13 | 5 | 4 | 2 | 190 |
| 14 | 15 | 17 | 19 | 9 | 11 | 11 | 9 | 12 | 7 | 4 | 3 | 117 |
| 15 | 5 | 19 | 19 | 22 | 10 | 13 | 9 | 8 | 7 | 0 | 2 | 108 |
| 16 | 6 | 9 | 12 | 11 | 19 | 5 | 6 | 5 | 7 | 5 | 3 | 80 |
| 18 | 2 | 8 | 7 | 20 | 18 | 19 | 17 | 9 | 9 | 9 | 7 | 135 |
| 21 | 6 | 12 | 23 | 17 | 20 | 12 | 8 | 5 | 0 | 3 | 1 | 107 |
| 22 | 45 | 72 | 74 | 81 | 77 | 70 | 62 | 54 | 30 | 18 | 17 | 600 |
| 25 | 2 | 19 | 15 | 13 | 20 | 22 | 18 | 7 | 6 | 3 | 6 | 131 |
| Other | 8 | 16 | 28 | 34 | 45 | 27 | 16 | 13 | 16 | 12 | 11 | 226 |
| TOTAL | 230 | 672 | 616 | 746 | 758 | 623 | 562 | 497 | 372 | 239 | 203 | 5518 |

TABLE II (3)

1971 GRADUATE-COUNT BY DISCIPLINE BY SECTOR BY AGE-GROUP OF THE PRINCIPAL SECTORS

MEDICALS

| Sector | 20-23 | 24-27 | 28-31 | 32-35 | 36-39 | 40-43 | 44-47 | 48-51 | 52-55 | 56-59 | 60-63 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 7 | 4 | 8 | 10 | 15 | 9 | 15 | 15 | 5 | 92 |
| 6 | 84 | 516 | 421 | 316 | 353 | 383 | 534 | 427 | 360 | 288 | 164 | 3846 |
| 9 | 4 | 10 | 11 | 12 | 8 | 15 | 22 | 18 | 13 | 14 | 4 | 131 |
| 13 | 24 | 39 | 54 | 59 | 95 | 157 | 175 | 149 | 116 | 113 | 95 | 1076 |
| 25 | 0 | 31 | 23 | 12 | 23 | 20 | 22 | 11 | 13 | 6 | 3 | 164 |
| Other | 6 | 7 | 7 | 6 | 10 | 9 | 13 | 14 | 14 | 18 | 7 | 111 |
| TOTAL | 120 | 605 | 523 | 409 | 497 | 594 | 781 | 628 | 531 | 454 | 278 | 5420 |

TABLE II (4)

1971 GRADUATE-COUNT BY DISCIPLINE BY SECTOR BY AGE-GROUP OF THE PRINCIPAL SECTORS

NATURAL SCIENTISTS

| Sector | 20-23 | 24-27 | 28-31 | 32-35 | 36-39 | 40-43 | 44-47 | 48-51 | 52-55 | 56-59 | 60-63 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13 | 23 | 35 | 17 | 20 | 27 | 22 | 19 | 11 | 16 | 8 | 211 |
| 6 | 18 | 30 | 17 | 21 | 9 | 10 | 4 | 7 | 3 | 3 | 3 | 125 |
| 7 | 8 | 12 | 38 | 28 | 16 | 9 | 5 | 2 | 1 | 3 | 0 | 122 |
| 9 | 19 | 45 | 50 | 36 | 18 | 28 | 19 | 16 | 14 | 23 | 18 | 286 |
| 10 | 126 | 221 | 39 | 46 | 70 | 71 | 54 | 33 | 58 | 58 | 50 | 1106 |
| 13 | 15 | 46 | 42 | 41 | 33 | 29 | 39 | 16 | 9 | 9 | 7 | 286 |
| 18 | 11 | 40 | 31 | 21 | 19 | 22 | 15 | 13 | 14 | 9 | 10 | 205 |
| 25 | 30 | 90 | 103 | 66 | 50 | 48 | 32 | 12 | 18 | 12 | 14 | 475 |
| Other | 37 | 61 | 77 | 67 | 35 | 41 | 37 | 29 | 16 | 18 | 16 | 434 |
| TOTAL | 277 | 568 | 632 | 443 | 270 | 285 | 227 | 147 | 134 | 141 | 126 | 3250 |

TABLE II (5)

GRADUATES BY SECTOR BY DISCIPLINE

| Sector | Agriculture/ Veterinary | | Engineers | | Medical/Dental/ Pharmacy | | Natural Science | |
|---|---|---|---|---|---|---|---|---|
| | 1967 | 1971 | 1967 | 1971 | 1967 | 1971 | 1967 | 1971 |
| 1 | 1047 | 1125 | 544 | 518 | 104 | 92 | 206 | 211 |
| 2 | 349 | 407 | 65 | 63 | 29 | 25 | 44 | 41 |
| 3 | 12 | 12 | 1087 | 1178 | 3 | 3 | 16 | 21 |
| 4 | 1 | 2 | 191 | 206 | 6 | 7 | 40 | 43 |
| 5 | 2 | 2 | 104 | 127 | 2 | 3 | 37 | 47 |
| 6 | 4 | 6 | 7 | 10 | 3612 | 3847 | 89 | 125 |
| 7 | 143 | 150 | 91 | 99 | 5 | 5 | 128 | 122 |
| 8 | - | - | - | - | - | - | - | - |
| 9 | 606 | 673 | 1087 | 1220 | 145 | 141 | 264 | 286 |
| 10 | 175 | 231 | 114 | 128 | 6 | 7 | 953 | 1106 |
| 11 | 7 | 7 | 104 | 116 | 0 | 0 | 43 | 45 |
| 12 | 3 | 5 | 188 | 232 | 2 | 4 | 32 | 39 |
| 13 | 54 | 66 | 167 | 190 | 1175 | 1076 | 245 | 286 |
| 14 | 4 | 4 | 104 | 117 | 1 | 1 | 5 | 8 |
| 15 | 5 | 5 | 98 | 108 | 1 | 1 | 23 | 15 |
| 16 | 4 | 5 | 76 | 80 | 2 | 2 | 4 | 4 |
| 17 | 3 | 3 | 42 | 50 | 6 | 6 | 51 | 42 |
| 18 | 642 | 742 | 136 | 135 | 23 | 21 | 171 | 205 |
| 19 | 3 | 3 | 13 | 14 | 2 | 2 | 1 | 2 |
| 20 | 9 | 10 | 39 | 34 | 7 | 7 | 24 | 27 |
| 21 | 4 | 4 | 101 | 107 | 1 | 1 | 20 | 24 |
| 22 | 2 | 3 | 550 | 600 | 2 | 3 | 35 | 40 |
| 23 | 3 | 4 | 58 | 55 | 12 | 13 | 38 | 33 |
| 25 | 104 | 116 | 115 | 131 | 137 | 164 | 402 | 475 |
| TOTAL | 3186 | 3585 | 5081 | 5518 | 5283 | 5431 | 2861 | 3248 |

TABLE III

GRADUATE EMPLOYMENT AND VOLUME OF GROSS OUTPUT BY SECTOR

| | Volume of Output | | Annual and | Graduates Employed | | Graduates per unit Gross output | | Annual and |
|---|---|---|---|---|---|---|---|---|
| | 1967 | 1971 | Increase | 1967 | 1971 | 1967 | 1971 | Trend |
| 1 | 61.0 | 71.0 | 3.9 | 1901 | 1946 | 31.2 | 27.41 | -3.2 (1) |
| 2 | 127.7 | 149.7 | 4.1 | 487 | 536 | 3.81 | 3.58 | -1.6 (2) |
| 3 | 133.4 | 174.0 | 6.8 | 1118 | 1214 | 8.35 | 6.98 | -4.4 (1) |
| 4 | 174.1 | 212.0 | 5.0 | 238 | 258 | 1.37 | 1.22 | -2.9 (2) |
| 5 | 20.2 | 26.1 | 6.6 | 145 | 179 | 7.18 | 6.56 | -1.1 (2) |
| 6 | 21.9 | 35.5 | 12.7 | 3712 | 3988 | 69.5 | 113.0 | -9.5 (1) |
| 7 | 1242.8 | 1476.0 | 4.4 | 330 | 376 | 0.295 | 0.255 | -3.6 (2) |
| 8 | 118.7 | 282.5 | 24.2 | 37 | 0 | - | - | - |
| 9 | 92.0 | 134.0 | 9.9 | 2102 | 2320 | 22.85 | 17.31 | -6.7 (1) |
| 10 | 34.9 | 49.9 | 9.1 | 1248 | 1472 | 35.96 | 29.80 | -4.5 (1) |
| 11 | 229.0 | 330.0 | 9.6 | 154 | 168 | 0.673 | 0.509 | -6.7 (2) |
| 12 | 29.9 | 35.2 | 4.2 | 225 | 281 | 7.56 | 7.98 | -1.5 (2) |
| 13 | 204.0 | 268.0 | 7.1 | 1641 | 1618 | 8.04 | 6.04 | -6.9 (1) |
| 14 | 47.4 | 55.8 | 4.2 | 114 | 130 | 2.41 | 2.33 | 0.7 (2) |
| 15 | 34.2 | 40.4 | 4.3 | 117 | 129 | 3.42 | 3.19 | -1.7 (2) |
| 16 | 7.9 | 9.3 | 4.2 | 86 | 91 | 10.89 | 9.78 | -2.6 |
| 17 | 104.6 | 140.8 | 7.7 | 102 | 1101 | 0.975 | 0.718 | -7.4 |
| 18 | 373.4 | 440.4 | 4.2 | 972 | 1103 | 2.60 | 2.50 | -1.0 (1) |
| 19 | 146.0 | 192.0 | 7.1 | 19 | 21 | 0.130 | 0.109 | -4.3 |
| 20 | 134.0 | 317.0 | 24.0 | 79 | 78 | 0.590 | 0.246 | -19.6 |
| 21 | 213.0 | 317.0 | 10.5 | 126 | 136 | 0.592 | 0.429 | -7.7 (2) |
| 22 | 43.8 | 51.9 | 4.3 | 589 | 646 | 13.45 | 12.45 | -1.9 (2) |
| 23 | 204.0 | 299.0 | 10.0 | 111 | 105 | .544 | 0.351 | 10.4 |
| 25 | - | - | - | 758 | 886 | - | - | - |
| | | | | 16411 | 17782 | | | |

TABLE IV

R & D MANPOWER AND EXPENDITURE

| Sector | Expenditure 1967 | Expenditure 1971 | Manpower 1967 | Manpower 1971 | Manpower/Expenditure 1967 | Manpower/Expenditure 1971 | Trend in R & D numbers per unit R & D cc |
|---|---|---|---|---|---|---|---|
| 1 | - | - | - | - | - | - | - |
| 2 | 2240.1 | 3848.9 | 286.1 | 313.4 | .128 | .0814 (1) | -10.5 |
| 3 | 101.9<br>10.0 = 119.9 | 230.8<br>55.1 = 258.9 | 2.2<br>17.0 = 19.2 | 25.5<br>4.7 = 30.2 | .1716 | .1056 (2) | -11.4 |
| 4 | 158.5<br>71.7 = 230.2 | 189.5<br>395.8 = 585.3 | 19.3<br>30.0 = 49.3 | 21.0<br>23.8 = 44.8 | .2142 | .0765 (2) | -22.7 |
| 5 | 0.4 | 39.6 | 0.2 | 4.0 | .500 | .101 | |
| 6 | 15.4 | 74.0 | 3.1 | 8.3 | .2013 | .1222 | |
| 7 | 385.7 | 1009.2 | 58.4 | 108.3 | .1514 | .1073 (1) | - 8.2 |
| 8 | 234.6 | 638.5 | 36.6 | 74.7 | .156 | .117 (1) | - 6.9 |
| 9 | 122.8 | 427.6 | 35.6 | 68.9 | .285 | .1611 (1) | -13.3 |
| 10 | - | - | - | - | - | - | - |
| 11 | 122.0 | 222.3 | 10.0 | 14.4 | .082 | .0645 (2) | - 5.8 |
| 12 | 236.1 | 484.4 | 32.0 | 45.1 | .1306 | .0931 (2) | - 8.1 |
| 13 | 346.8 | 558.3<br>211.3 = 769.6 | 58.3 | 55.0<br>17.8 = 72.8 | .1514 | .0946 (1) | -11.1 |
| 14 | 19.6 | 220.5 | 5.0 | 7.6 | .2551 | .0345 | |
| 15 | 86.9 | 245.0 | 16.8 | 12.7 | .1488 | .0518 (2) | -23.2 |
| 16 | 25.0 | 151.1 | 4.5 | 6.1 | .180 | .0404 | |
| 17 | 135.1 | 306.3 | 9.0 | 15.5 | .1041 | .0506 (2) | -16.5 |
| 18 | 680.8 | 1155.5 | 86.4 | 80.3 | .1265 | .0695 (1) | -13.9 |
| 19 | 14.0 | 8.2 | - | - | - | - | - |
| 20 | 49.9 | 158.6 | 10.0 | 8.1 | .1923 | .0511 | |
| 21 | 81.2 | 154.7 | 11.1 | 12.2 | .1367 | .0789 (2) | -12.8 |
| 22 | 106.3 | 461.4 | 25.0 | 100.2 | .2352 | .2172 (1) | - 2.0 |
| 23 | 57.0 | 651.6 | 8.1 | 54.8 | .1421 | .0841 (2) | |

TABLE V

(a) GRADUATE OUTPUT, BY DISCIPLINE, BY YEAR, OF THE HIGHER EDUCATION SYSTEM (primary degrees only)

| Faculty \ Year | 1966/67 | 1968/69 | 1970/71 | 1971/72 | |
|---|---|---|---|---|---|
| Arts | 1558 | 1670 | 2013 | 2521 | |
| Agriculture | 99 | 120 | 143 | 140 | 1 |
| Veterinary Med. | 73 | 55 | 39 | 75 | 1 |
| Commerce | 325 | 316 | 450 | 513 | |
| Social Sc. | 53 | 115 | 116 | 132 | |
| Medicine | 237 | 273 | 311 | 275 | 3 |
| Dentistry | 46 | 39 | 42 | 45 | 3 |
| Law | 63 | 116 | 133 | 126 | |
| Engineering | 228 | 234 | 221 | 292 | 2 |
| Architecture | 12 | 24 | 44 | 15 | 2 |
| Science | 378 | 412 | 401 | 482 | 4 |
| TOTALS | 3072 | 3380 | 3913 | 4616 | |

(b) ) AGGREGATED GRADUATE OUTPUT, BY DISCIPLINE BY YEAR, OF THE HIGHER EDUCATION SYSTEM

| Faculty \ Year | 1966/67 | 1968/69 | 1970/71 | 1971/72 |
|---|---|---|---|---|
| Agriculture | 172 | 175 | 182 | 215 |
| Engineering | 240 | 258 | 265 | 307 |
| Medicine | 283 | 312 | 353 | 320 |
| Natural Science | 378 | 412 | 401 | 482 |
| TOTAL | 1073 | 1157 | 1201 | 1324 |

## TABLE VI

## R & D NUMBERS, R & D COST, TOTAL EXPENDITURE AND GRADUATE OUTPUT IN HIGHER EDUCATION

| | Total Expenditure | | | R & D Expenditure (£000) | |
|---|---|---|---|---|---|
| | 1967 | 1971 | 1972 | 1967 | 1971 |
| Agricultural Sciences | 713.3 | 1510.0 | 1859.9 | 92 | 167 |
| Engineering & Technology | 516.0 | 1230.0 | 1538.8 | 125 | 183 |
| Medical Sciences | 632.5 | 1570.0 | 1992.4 | 194 | 360 |
| Natural Sciences | 1191.0 | 2950.0 | 3768.0 | 498 | 681 |

| | R & D Manpower | | Graduate output | | Estimated accumul. |
|---|---|---|---|---|---|
| | 1967 | 1971 | 1966/67 | 1971/72 | 4-year output |
| Agricultural Sciences | 33.6 | 51.8 | 172 | 215 | 761 |
| Engineering & Technology | 59.4 | 75.5 | 240 | 307 | 1084 |
| Medical Sciences | 63.6 | 92.2 | 283 | 320 | 1198 |
| Natural Sciences | 270.3 | 307.8 | 378 | 482 | 1697 |

TABLE VII

SECTION 22: ENGINEERS IN THE UTILITIES SECTOR

| Age | 1967 | 1971 | 1975 | 1979 | Survival | Inverse |
|---|---|---|---|---|---|---|
| 20-23 | (46†) | 45 | -(45†) | - | .996 | 1.004 |
| 24-27 | 74 | 72 | 44(72†) | 44† | .995 | 1.005 |
| 28-31 | 81 | 74 | 71 | 71† | .995 | 1.005 |
| 32-35 | 77 | 81 | 73 | 71 | .993 | 1.007 |
| 36-39 | 70 | 77 | 80 | 72 | .991 | 1.009 |
| 40-43 | 63 | 70 | 76 | 79 | .988 | 1.012 |
| 44-47 | 55 | 62 | 69 | 75 | .982 | 1.018 |
| 48-51 | 31 | 54 | 60 | 67 | .972 | 1.028 |
| 52-55 | 19 | 30 | 52 | 58 | .957 | 1.044 |
| 56-59 | 18 | 18 | 28 | 50 | .939 | 1.064 |
| 60-63 | (16) | 17 | 16 | 26 | .911 | 1.097 |

† Estimated figures

The end-effects we take care of as follows.

Case 1 1967 age-group 20-23: preserve the ratio of the first two age groups.

Case 2 1967 age-group 60-63: relate to a smoothed tail-profile.

Case 3 1975 age-group 20-23: this is the gap into which the new cohort will come, in the model. We treat this in the next section, when we come to describe the projection procedure. At this point however we can usefully define the 'attrition coefficient' : the ratio of the year N+4 stock without the 20-23 age-group, as listed above, to the year N stock.

In order to get the attrition coefficients for projection step 2, we have to fill in estimates (†) of the 20-23 and 24-27 age groups of the 1975 distribution, conforming to the 1971 profile. In the case of 1979, the estimation extends up to the 28-31 group.

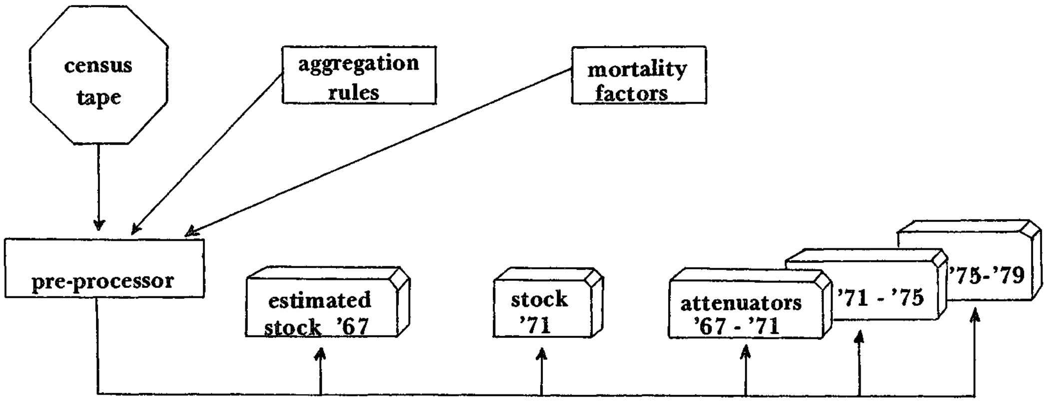
Thus the determination of the attrition coefficients is an approximate procedure; it is a device for abstracting from the details of age-distributions in the main projection programme, which deals in total stock by sector and discipline but not by age.

This approximation becomes worse the further one attempts to go into the future.

The above calculations were carried out by the pre-processor, at the same time as the basic census data were aggregated. Any re-run with different aggregation rules would of course give revised attrition-arrays.

A block diagram of the pre-processor system is shown in Figure 1:

FIGURE 1:




All necessary measures for 1967 and 1971 being available, the calculation of trends for the various relevant ratios was a simple matter. We wrote a small utility programme to determine the annual percentage increase necessary to relate two measures and their ratio over a period of N years.

Tables VIII and IX show the remainder of the inputs necessary for the model, with the trends displayed explicitly. Other trends, such as graduates per unit gross output and R & D manpower per unit expenditure are included in Tables III and IV respectively.

It will be noted that we have adopted a procedure for concentrating attention where the numbers are large. Referring to Table III, the trends labelled (1) were treated individually: these were the top seven graduate-employing sectors. Those labelled (2) were folded into a background average trend; the unlabelled ones, being small-number based, were ignored.

Similarly the top seven R & D graduate employers were treated separately (trends subscripted (1) in Table IV) and the remainder labelled (2) were folded into a background.

We note in passing the following:

1. The following are in the 'top seven' for both R & D manpower and graduate manpower: finance & commerce; chemicals, rubber, plastic; food, drink, tobacco.

2. The following are in the 'top seven' for graduate employment but not for R & D: central and local government, building and construction, health services, education other than 3rd level.

3. The following are in the 'top seven' for R & D but not for general graduate employment: agriculture, state planning and research, development area, and physical planning and utilities.

We can also usefully consider the relationship between the output of graduates and the numbers employed in the 24-27 age-group, as it was in 1971. This age-group represents the cohort graduating in or about the period 1966-69.

TABLE VIII

R & D EXPENDITURE/TOTAL H.E. EXPENDITURE

| | 1967 | 1971 | Annual percentage trend |
|---|---|---|---|
| Agricultural Science | 0.1290 | 0.1106 | -3.8 |
| Engineering & Technology | 0.2422 | 0.1488 | -11.5 |
| Medical Sciences | 0.3067 | 0.2293 | -7.0 |
| Natural Sciences | 0.4181 | 0.2308 | -13.8 |

ACADEMIC STAFF/TOTAL H.E. EXPENDITURE

| | 1967 | 1971 | Annual percentage trend |
|---|---|---|---|
| Agricultural Sciences | 0.1458 | 0.0768 | -14.8 |
| Engineering & Technology | 0.2229 | 0.1065 | -16.9 |
| Medical Sciences | 0.2166 | 0.1045 | -16.7 |
| Natural Sciences | 0.3375 | 0.1610 | -16.9 |

TABLE IX

RESEARCH AND DEVELOPMENT COSTS (SEE TABLE IV) PER UNIT VOLUME OF OUTPUT BY SECTOR (TABLE III)

| Sector | 1967 | 1971 | Annual Percentage trend |
|---|---|---|---|
| 1 | 0 | 0 | - |
| 2 | 17.54 | 25.71 | 10.0 (1) |
| 3 | 0.836 | 1.643 | 18.4 (2) |
| 4 | 1.322 | 2.761 | 20.2 (2) |
| 5 | .0148 | 1.517 | 195.9 |
| 6 | .7032 | 2.096 | 31.4 |
| 7 | .3103 | 0.684 | 21.8 (1) |
| 8 | 1.976 | 2.260 | 3.4 (1) |
| 9 | 1.335 | 2.191 | 24.3 (1) |
| 10 | - | - | - |
| 11 | 0.533 | 0.677 | 6.2 (2) |
| 12 | 8.194 | 13.76 | 13.8 (2) |
| 13 | 1.877 | 2.872 | 11.2 (1) |
| 14 | 0.414 | 3.952 | 75.8 |
| 15 | 3.301 | 6.064 | 16.4 (2) |
| 16 | 3.165 | 16.25 | 50.5 |
| 17 | 1.304 | 2.176 | 13.7 (2) |
| 18 | 1.829 | 2.624 | 9.4 (1) |
| 19 | .0959 | 0.0427 | -18.3 |
| 20 | .3881 | 0.5003 | 6.6 |
| 21 | .381 | 0.488 | 6.4 (2) |
| 22 | 2.427 | 8.890 | 38.3 (1) |
| 23 | .2794 | 2.179 | 67.1 (2) |
| 24 | | | |

(1) 'top seven' sectors as regards 1971 manpower.

(2) other sectors with manpower exceeding 10 in 1971.

Taking a mean between the graduate outputs for the academic years 1966/67 and 1968/69, and expressing the four-year cohort as jobs per year, we get the results displayed in Table X.

TABLE X

| | 1971 Jobs in 24-27 age-group | Jobs per year | Annual supply of graduate in '66-'69 |
|---|---|---|---|
| Agriculture | 522 | 131 | 173 |
| Engineering | 672 | 168 | 249 |
| Medicine | 598 | 150 | 297 |
| Natural Sciences | 568 | 142 | 395 |

This shows a very considerable degree of under-consumption of science graduates, or over production relative to effective demand. Engineers are more nearly in balance, as are agriculturalists. Medicals are possibly inflated due to a strong foreign student component, by tradition.

The existence of this imbalance makes the projection model, described in the next section, of some interest, in that it can be used to evaluate how the degree of imbalance responds to policy changes, particularly with regard to R & D.

## CONSTRUCTION OF THE MODEL

In this section we define the elements of the system which we model, and specify the manner in which it is hypothesised to interact with the environment. We suggest a short-list of policy variables which may be regarded as subject to control by the State.

We describe the steps whereby supply and demand are projected, and suggest an adjustment mechanism, without however going into the question of price. (By and large the price may be regarded as externally determined, or at least influenced.)

The system falls naturally into two parts: a production/services segment, made up of 23 sectors, and a higher education segment, which may be regarded as a 24th sector having special properties. This is not simply a 'demand' segment and a 'supply' segment: the 'demand' extends into the higher education segment, which has to feed itself with recruits, as well as supplying the production/services segment.

Consider first the definition of the system and its measures in the base-year.

We have in the production/services segment the following inputs:

(1) a graduate stock array, 23 sector by 4 disciplines.

(2) a gross output vector for 23 sectors.

(3) an 'R & D graduate equivalent' vector for 23 sectors.

(4) an 'R & D expenditure' vector for 23 sectors.

With these inputs we construct the following secondary variables:

(a) From (1) we construct a set of 'split-vectors': the fraction of graduates of each discipline employed in each sector.

(b) Subtracting (3) from (1) and dividing by (2) we construct a vector for the 23 sectors which gives 'non-R & D graduates per unit of gross output'. This is hypothesised to measure the general graduate employment level, irrespective of the R & D effort, as a function of economic activity.

(c) Dividing (4) by (2) we get a vector 'R & D expenditure per unit gross output'.

(d) Dividing (3) by (4) we get a vector 'R & D graduate equivalent per unit R & D expenditure'.

Turning to the Higher Education segment, this constitutes a 24th sector but is treated in more detail, in that each of the measures is broken out over the four disciplines. We do not depend on a set of 'split-vectors' operating on an aggregated value, but keep the measures disaggregated. We have the following inputs in the form of discipline-vectors (8 elements, of which we are using 4):

(5) graduate output
(6) graduate staff
(7) higher education expenditure
(8) R & D graduate equivalent
(9) R & D expenditure

With the above inputs we construct the following secondary variables:

(e) Dividing (5) by (7) we get 'graduate output per unit of higher education (H. E.) expenditure'.

(f) Subtracting (8) from (6) and dividing by (7) we get 'teaching graduate equivalent per unit H.E. expenditure'.

(g) Dividing (9) by (7) we get 'R & D expenditure per unit H.E. expenditure'.

(h) Dividing (8) by (9) we get 'R & D graduates per unit R & D expenditure'.

The measures of the system and the environment in the base-year are now fully defined.

The interaction between the system and the environment is defined by means of the hypotheses

(A) that there is a linear proportionality between economic activity as measured by gross output and non- R & D' graduate employment.

(B) that there is a linear proportionality between R & D expenditure and R & D graduate employment.

(C) that the coefficients in the above linear relationships are themselves subject background trends reflecting environmental changes (e.g. productivity, inflation etc).

We are now in a position to define the projection procedure. We use a four-year increment. The steps are set out in block diagram form in Figures 2 and 3.

First we update those secondary variables (i.e. the coefficients in the assumed linear relationships) which are subject to background trends as follows:

(b) combined productivity and inflation;

(d) and (h) combined inflation and trend towards 'capital-intensiveness': improved equipment etc;

FIGURE 2

PRODUCTION / SERVICES SERVICES

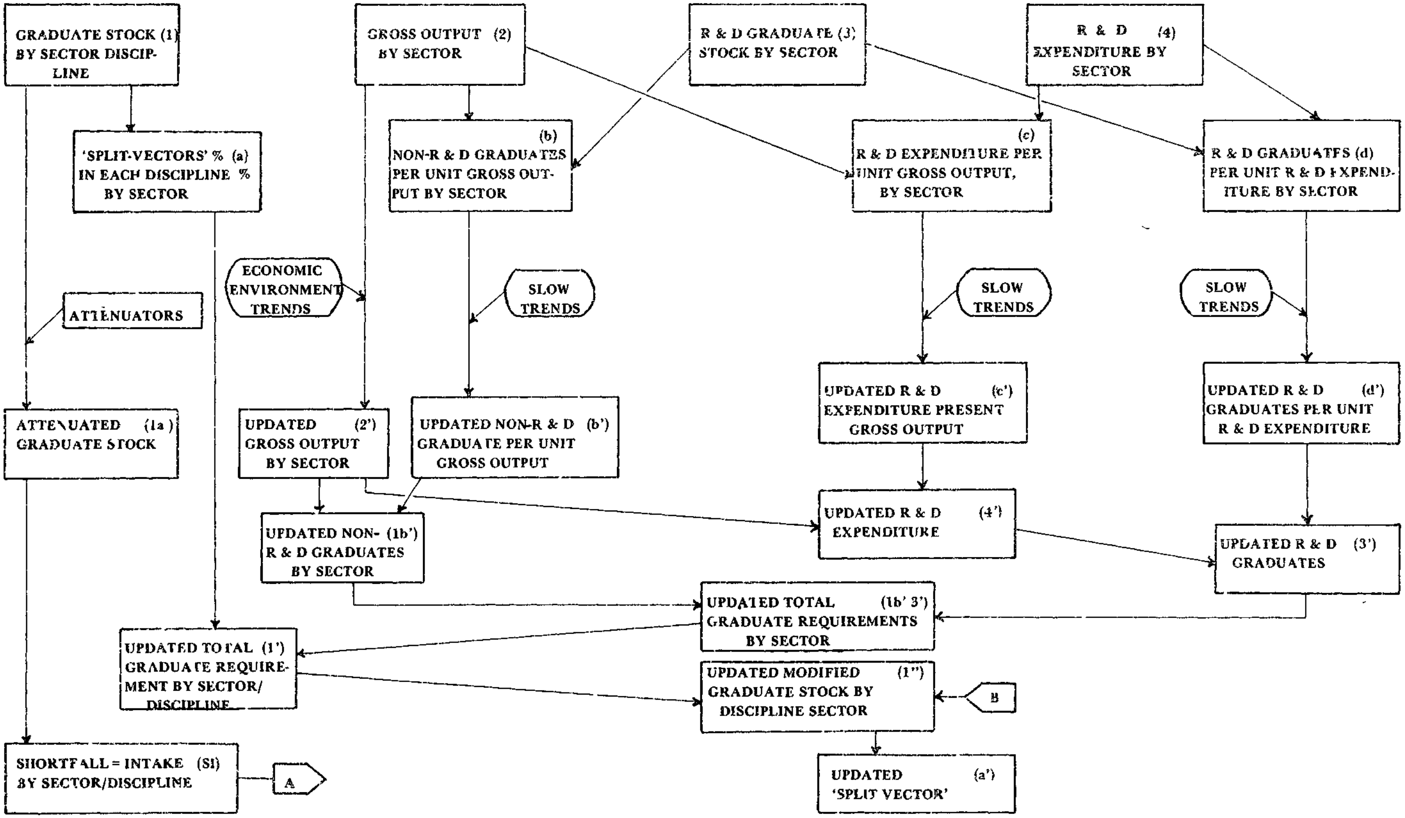
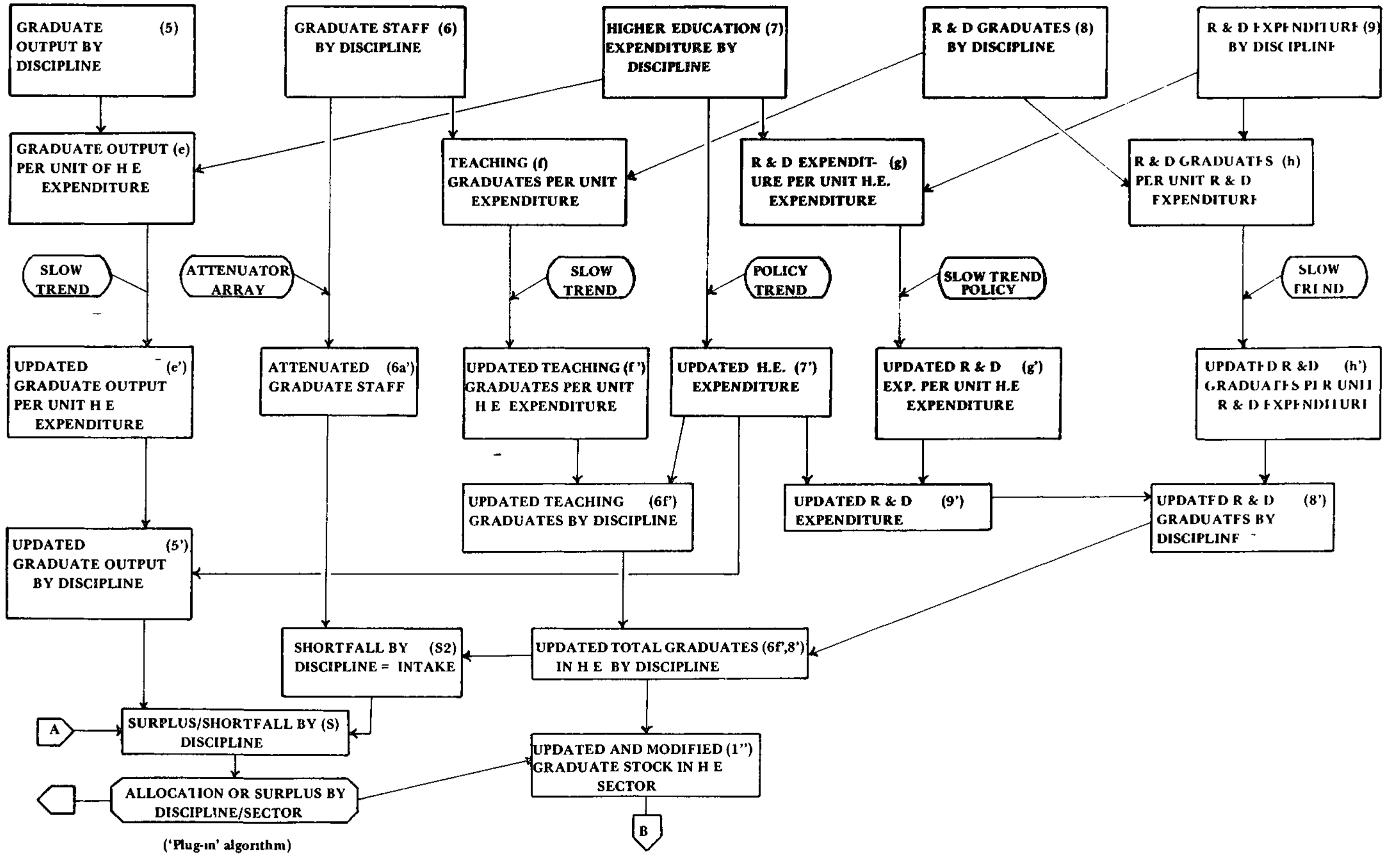


FIGURE 3

HIGHER EDUCATION SEGMENT



(e) and (f) mainly inflation.

Then we update those coefficients which are subject to state policy:

(c) and (g): both these can be influenced by tax rebates, grants and other incentives by bodies such as the NSC (or now the National Board for Science and Technology).

Finally we update the basic economic background variables (2) and the H.E. expenditure (7).

We are now in a position to update the graduate demand. Denoting henceforth the updated variables by 'prime', we go through the following steps (see Figure 2).

(2') x (b') $\rightarrow$ 'non R & D graduates by sector' (1b')
(2') x (c') $\rightarrow$ (4')
(4') x (d') $\rightarrow$ (3')
(1b') + (3') $\rightarrow$ (1b, 3').

We now have (1b,3) which is the updated graduate requirements by sector, but not by discipline. To bring in the disciplines we operate on it with the 'split-vectors' (a) and end up with (1') which is an updated graduate stock demand array.

We are assuming that there is short-term stability in the 'split-vectors' (a): We do, however, subsequently modify (a) in the light of a proposed adjustment mechanism, so that it does in the end act as a slow dependent variable, with a one-period lag.

The updated total demand (1') will be satisfied by two sources: the old stock attenuated by death and retirement and by new recruits.

We construct an attenuated stock array (1a') by operating on the base-year stock array (1) with the attenuator array, which has been read in as input. (It will be remembered that one of the tasks of the pre-processor was to abstract the age-distributions into survival factors for each discipline and sector; see Figure 1.)

Subtracting (1a') from (1') gives S1, the recruitment necessary by sector and discipline. This is available for comparison with the graduate output given by the Higher Education segment.

We now consider the higher education sector and compute the demand for the graduates necessary for its maintenance, as well as the supply of graduates which it produces.

Referring to Figure 3, we go through the following steps:

(7') x (f') $\rightarrow$ 'teaching graduate equivalent by discipline' (6f')
(7') x (e') $\rightarrow$ (5')
(7') x (g') $\rightarrow$ (9')
(9') x (h') $\rightarrow$ (8')
(8') + (6f') $\rightarrow$ (6f', 8')

We now have the updated graduate requirements by discipline, for teaching and research, in the H.E. sector. This will be satisfied by the attenuated old stock (6a') and new recruits; the latter are given by

(6f', 8') – (6a') $\rightarrow$ (S2)

We are now in a position to establish an overall graduate balance:

(5') – (S1) – (S2) $\rightarrow$ (S)

In the context of contemporary Ireland this in all cases is a positive surplus, so that in the present model we have not had to introduce a mechanism for dealing with deficiencies. To do so would not present a problem, as regards the subsequent computational steps.

In order to take care of the surplus, we have introduced a hypothesis which we call the 'soak process'. We assume that a certain fraction of the surplus of each discipline is absorbed into the updated graduate stock, and that the 'soak' from each discipline spreads itself across the sectors in proportion as it is already there.

The fraction of surplus thus 'soaked up' we estimate using an arbitrary algorithm which quantifies the following hypothesis: if an emigration tradition exists it will tend to persist; if the tradition is not to emigrate, the surplus graduate will stay and be soaked up. Thus the greater the surplus is, the smaller its tendency to be soaked up.

The parameters of this hypothesis are a proper subject for sociological studies on graduate emigration. In the present study, we acknowledge that it is an arbitrary *ad hoc* assumption.

It is by no means essential to the model that this particular hypothesis be adopted. It constitutes a 'plug-in' module of the programme which could in a subsequent run be replaced by some alternative hypothesis.

We felt,however,that we needed to introduce some such mechanism, in order to avoid the criticism that the 'split-vectors' ((a), Figure 2) were invariant, and that this was artificial. We needed a mechanism for introducing slow change, under the influence of the 'push' of the output from the H.E. system. We submit that, however arbitrary this assumption seems, it would be even less defensible to impose the strait-jacket of invariant discipline-mixes in all sectors.

The final step in the cycle is therefore to adjust the updated graduate stock (1') with the 'soak' fraction of the surplus (S), giving the 'modified stock' (1"), which is then used to establish an updated set of 'split-vectors' (a') for use in the next cycle.

The cycle is then repeated, for as many steps as one likes. In practice, we doubt if more than 3 or 4 steps would be meaningful, in view of the approximations in the determination of the attenuation-array. However 12-16 years seems a reasonable planning horizon for this type of exercise.

PROJECTIONS TO 1979

Before carrying out a projection, it is useful to validate the model by applying it to the period 1967-71. This is a non-trivial step, in that it is useful to check that the approximations which we have made (e.g. separate trends for the 'top seven' sectors against an averaged background, etc) are not too sweeping.

It is also useful to be able to 'fine-tune' the model using those trends of which the value is least well known as 'fitting parameters'.

This we have done, and the result is displayed in Table XI (1). It will be seen that the projected and actual versions as the 1971 stock are in reasonable agreement.

We allowed the model to run on, on present trends. The surplus pattern which emerged is shown in Table XI (2). We refer on this as Run (a).

Then we started to amend the inputs. In this study we have not explored fully the many combinations possible. We confined ourselves to three alternative 'scenarios', as follows:

Run (b) : 2.6 percentage points reduction in annual growth of volume of output, across all sectors, after 1971.

Run (c) : as for (b) but with 20 percentage points increase in trend in R & D expenditures per unit volume of output on all but three already well-developed sectors.

Run (c) : 5.3 percentage points reduction in annual growth of volume of output, across all sectors, after 1971.

If these runs seem pessimistic, may we say that their strategy was decided at the height of the oil crisis.

TABLE XI (1) Run (a)

PROJECTED GRADUATE STOCK AT WORK, BY SECTOR, PRESENT TRENDS

| Sector | 1967 | 1971 (1) | 1971 (2) | 1975 | 1979 |
|---|---|---|---|---|---|
| 1 | 1901 | 1946 | 1946 | 2000 | 2206 |
| 2 | 487 | 556 | 536 | 637 | 733 |
| 3 | 1118 | 1205 | 1214 | 1309 | 1429 |
| 4 | 238 | 256 | 258 | 278 | 302 |
| 5 | 145 | 153 | 179 | 162 | 172 |
| 6 | 3712 | 3974 | 3988 | 4258 | 4577 |
| 7 | 330 | 405 | 376 | 491 | 617 |
| 8 | 37 | 41 | - | 45 | 50 |
| 9 | 2102 | 2342 | 2320 | 2612 | 2936 |
| 10 | 1248 | 1470 | 1472 | 1735 | 2055 |
| 11 | 154 | 164 | 168 | 175 | 188 |
| 12 | 225 | 240 | 281 | 258 | 279 |
| 13 | 1641 | 1643 | 1618 | 1654 | 1676 |
| 14 | 114 | 119 | 130 | 126 | 134 |
| 15 | 117 | 125 | 124 | 134 | 145 |
| 16 | 86 | 90 | 91 | 95 | 101 |
| 17 | 102 | 111 | 101 | 121 | 132 |
| 18 | 972 | 1088 | 1103 | 1224 | 1385 |
| 19 | 19 | 20 | 21 | 21 | 22 |
| 20 | 79 | 85 | 78 | 92 | 99 |
| 21 | 126 | 134 | 136 | 143 | 153 |
| 22 | 589 | 693 | 646 | 830 | 1080 |
| 23 | 111 | 118 | 105 | 127 | 137 |
| 24 | - | - | - | - | - |
| 25 | 758 | 946 | 886 | 1044 | 1261 |
| TOTAL | 16411 | 17923 | 17782 | 19571 | 21732 |

(1) output from model derived from 1967 base-year
(2) actual census output.

TABLE XI (2) Run (a)

GRADUATE OUTPUT, TAKE-UP AND EMIGRATION

| Year | Quantity | Agricultural Scientists | Engineers | Medicals | Natural Scientists |
|---|---|---|---|---|---|
| 1967 | Annual Output | 172 | 240 | 283 | 378 |
| 1971 | 4-year cumulative output | 761 | 1084 | 1198 | 1697 |
| | Take-up | 525 | 888 | 840 | 814 |
| | Surplus | 236 | 196 | 358 | 883 |
| | Annual Output | 202 | 291 | 310 | 454 |
| 1975 | 4-year cumulative output | 893 | 1313 | 1311 | 2036 |
| | Take-up | 561 | 997 | 834 | 851 |
| | Surplus | 332 | 316 | 477 | 1185 |
| | Annual Output | 237 | 352 | 339 | 544 |
| 1979 | 4-year cumulative output | 1048 | 1590 | 1435 | 2444 |
| | Take-up | 699 | 1242 | 1097 | 1054 |
| | Surplus | 349 | 348 | 338 | 1399 |
| | Annual Output | 278 | 427 | 371 | 653 |

TABLE XII (1) Run (b)

PROJECTED GRADUATE STOCK AT WORK, ASSUMING 2.6 PERCENTAGE POINTS REDUCTION ON TREND IN VOLUME OF OUTPUT ACROSS ALL SECTORS, AFTER 1971

| | 1975 | | 1979 | |
|---|---|---|---|---|
| Sector | Projection (a) | This Projection | Projection (a) | This Projection |
| 1 | 2000 | 1706 | 2065 | 1517 |
| 2 | 637 | 545 | 733 | 544 |
| 3 | 1309 | 1138 | 1429 | 1093 |
| 4 | 278 | 241 | 304 | 231 |
| 5 | 162 | 140 | 172 | 129 |
| 6 | 4258 | 3661 | 4577 | 3463 |
| 7 | 491 | 423 | 617 | 464 |
| 8 | 45 | 39 | 56 | 39 |
| 9 | 2612 | 2262 | 2936 | 2223 |
| 10 | 1735 | 1499 | 2055 | 1536 |
| 11 | 175 | 151 | 188 | 142 |
| 12 | 258 | 224 | 279 | 212 |
| 13 | 1654 | 1412 | 1676 | 1248 |
| 14 | 126 | 109 | 134 | 102 |
| 15 | 134 | 116 | 145 | 110 |
| 16 | 95 | 83 | 101 | 77 |
| 17 | 121 | 104 | 132 | 99 |
| 18 | 1224 | 1047 | 1385 | 1020 |
| 19 | 31 | 18 | 22 | 16 |
| 20 | 92 | 79 | 99 | 74 |
| 21 | 143 | 123 | 153 | 116 |
| 22 | 830 | 723 | 1080 | 834 |
| 23 | 127 | 110 | 137 | 103 |
| 25 | 1044 | 1078 | 1261 | 1288 |
| TOTAL | 19671 | 17030 | 21732 | 16679 |

It is useful however to be able to compare projections (b) and (c): it looks as if the development of a more agressive R & D policy would have an appreciable impact on the graduate surplus. It is not outside the reach of the State to allow R & D expenditure to double over four years, thereby arriving at a figure of over 20 per cent of graduates in industry engaged in R & D, compared with the current 10 per cent. The figure for the UK is reputed currently to be of the order of 30 per cent.

Since we are already in 1975, one step of the model's progress away from the base-year 1971, it is useful to look at the Graduate Placement Report of the Association of Irish University Careers and Appointments Services.

In 1973, of the 414 science graduates 352 were traceable, and of these 85 were in employment. The remainder were mostly in one or another kind of further study, mainly teacher training (120).

Of the 275 engineers, 245 responded and 136 were in employment, only 30 being in further study.

Thus although there is not an exact reconciliation between the figures, the picture emerges of a pool of unemployed science graduates, hoping by research to obtain an entry into the academic system, into which the annual intake might be of the order of 20 or 30, if the age-distribution for sector 25 given in Table II (4) is anything to go by.

No statistics are available for the flows of higher-degree students. The indication of this study is that the majority of them emigrate.

## DISCUSSION AND CONCLUSIONS

Given that the problem is basically one of relative over-production of specialist scientists, there are various courses of action open to a Government concerned with optimal allocation of national resources.

(1) To run down expenditure on the Higher Education System selectively until the output matches the present input needs of industry.

This would be a reasonable course of action if it could be demonstrated that the present level of scientific technology in industry was in some way optimal. The general concensus (cf the Cooper-Whelan report 'Science, Technology and Industry in Ireland', published by the National Science Council, January 1973) is that this is far from being the case.

(2) To encourage by subsidy or other device the ingestion of the present graduate output into industry. This, however, might be counter-productive if, for example, the 'cultural gap' between the surplus science graduates and the current problem areas in industrial technology was such as to block mutual understanding. There is some evidence, at the level of case-histories known to us, thus this is so.

(3) To develop a re-orientation programme for specialist graduates such as to familiarise them with practical industrial problems. These re-orientation programmes could be aimed at:

(a) young graduates;

(b) mature specialists in State research institutes who wish to generalise themselves towards management.

TABLE XII (2)

GRADUATE OUTPUT, TAKE-UP AND EMIGRATION Run (b)

| Year | Quantity | Agricultural Scientists | Engineers | Medicals | Natural Scientists |
|---|---|---|---|---|---|
| 1967 | Annual Output | 172 | 240 | 283 | 378 |
| 1971 | 4-year cumulative output | 761 | 1084 | 1198 | 1697 |
| | Take-up | 525 | 888 | 840 | 814 |
| | Surplus | 236 | 196 | 358 | 883 |
| | Annual | 202 | 291 | 310 | 454 |
| 1975 | 4-year cumulative output | 893 | 1313 | 1311 | 2036 |
| | Take-up | 17 | 238 | 22 | 372 |
| | Surplus | 876 | 1075 | 1289 | 1664 |
| | Annual Output | 237 | 352 | 339 | 544 |
| 1979 | 4-year cumulative output | 1048 | 1590 | 1435 | 2444 |
| | Take-up | 120 | 395 | 320 | 442 |
| | Surplus | 928 | 1195 | 1115 | 2002 |
| | Annual Output | 278 | 427 | 371 | 653 |

TABLE XIII (1) Run (c)

PROJECTED GRADUATE STOCK AT WORK, ASSUMING 2.6 PERCENTAGE POINTS REDUCTION ON TREND IN VOLUME OF OUTPUT ACROSS ALL SECTORS AFTER 1971, WITH 20 PERCENTAGE POINTS INCREASE IN TREND IN R & D EXPENDITURE PER UNIT VOLUME OF OUTPUT ON ALL BUT THREE ALREADY WELL DEVELOPED SECTORS

| Sector | 1975 Projection (b) | 1975 This Projection | 1979 Projection (b) | 1979 This Projection |
|---|---|---|---|---|
| 1 | 1706 | 1749 | 1517 | 1557 |
| 2 | 545 | 557 | 544 | 555 |
| 3 | 1138 | 1197 | 1093 | 1155 |
| 4 | 241 | 301 | 231 | 294 |
| 5 | 140 | 144 | 129 | 134 |
| 6 | 3661 | 3718 | 3463 | 3530 |
| 7 | 423 | 431 | 464 | 472 |
| 8 | 34 | 102 | 39 | 100 |
| 9 | 2262 | 2384 | 2223 | 2320 |
| 10 | 1449 | 1526 | 1536 | 1567 |
| 11 | 151 | 166 | 142 | 157 |
| 12 | 224 | 265 | 212 | 255 |
| 13 | 1412 | 1519 | 1248 | 1368 |
| 14 | 109 | 118 | 102 | 111 |
| 15 | 116 | 138 | 110 | 132 |
| 16 | 83 | 90 | 77 | 84 |
| 17 | 104 | 122 | 94 | 118 |
| 18 | 1047 | 1144 | 1020 | 1107 |
| 19 | 18 | 18 | 16 | 17 |
| 20 | 79 | 92 | 74 | 88 |
| 21 | 123 | 139 | 116 | 132 |
| 22 | 723 | 743 | 834 | 854 |
| 23 | 110 | 121 | 103 | 115 |
| 25 | 1078 | 1069 | 1258 | 1294 |
| TOTAL | 17030 | 17851 | 16679 | 17567 |

The first option is unacceptable, because if there is a decline in the quality of the basic science teaching and research in the universities, in the long run the teaching of engineers will degenerate to text-book procedures, producing rapidly obsolescent engineers.

The second option on its own, as explained above, would be counter-productive.

If the second option were to be supplemented by the third, however, there could be a dramatic increase in the level of technological understanding available to Irish industry, in quite a short time.

We now attempt to define this re-orientation process.

In the case of the Agricultural and Engineering graduates, absorption into economic life is limited by the 'permanent and pensionable job' psychology associated with large State and semi-State establishments. (See age-distributions, Table II).

This problem could be resolved by tackling the promotion-blocking middle age-groups in these bodies.

If there were to be arranged a 'a controlled leak' of experienced agriculturalists and engineers from these age-groups into economic life in an entrepreneurial or management capacity, the way would be cleared for a dynamic flow of energetic young people into (and after say 10-15 years, out of) the State and semi-State systems.

Such a flow exists to some extent in the case of Aer Lingus.

What is needed is the development of 'mature graduate re-orientation schemes'; the possibility for a man in the age-bracket 35-45 to take a year off and do a course in business studies, industrial engineering or other such management oriented discipline. He would then be on the market for management or entrepreneurial talent, possibly with some capital. He should keep his pension rights with his ex-employer in full. This possibly requires legislation.

In the case of the agriculturalists, there is the potential for developing an expanding market for agricultural scientific talent, combined with management ability, in the management of farm business systems.

Starting modestly, it should be possible to re-train say 50 per annum mature specialists from each of these two disciplines at cost to the state not exceeding £300,000. This seems a relatively cheap way of introducing some dynamics into the agricultural and engineering scene.

We leave aside the medicals, as they are not really within the scope of this study.

In the case of the natural scientists, it is necessary to adopt a different approach.

There exists a belief that there are direct, cause-effect relationships between science, technology and industry. No such direct relationships exist *a priori:* they have to be generated. The science graduate, as such, is of little use to industry in Ireland at this point in time.

The science graduate is, however, of great *potential* use, both in management and in industrial technology, because of his quantitative grasp of the complexities of interacting systems. This potential can be taken up by a re-orientation procedure. It is in the interest of those responsible for the survival and development of Irish industry to finance this re-orientation.

It is necessary to provide re-orientation for about 300 science graduates per annum. This would cost, if an adequate grant scheme were provided, a further £300,000 per annum in maintenance.

The type of re-orientation course which would attract them, and produce an employable output, would be in the form of an M.Sc., oriented towards a particular area of technology, with a strong scientific base.

Suitable labels for a 'scientific technology M.Sc.' might be: food, marine, environmental, transportation, petro-chemical etc.

Existing masters-degree courses in dairy science, computer science, industrial engineering, operational research and statistics etc. are pointers.

TABLE XIII (2)

GRADUATE OUTPUT, TAKE-UP AND EMIGRATION Run (c)

| Year | Quantity | Agricultural Scientists | Engineers | Medicals | Natural Scientists |
|---|---|---|---|---|---|
| 1967 | Annual Output | 172 | 240 | 283 | 378 |
| 1971 | 4-year cumulative output | 761 | 1084 | 1198 | 1697 |
| | Take-up | 525 | 888 | 840 | 814 |
| | Surplus | 236 | 196 | 358 | 883 |
| | Annual Output | 202 | 291 | 310 | 454 |
| 1975 | 4-year cumulative Output | 893 | 1313 | 1311 | 2036 |
| | Take-up | 161 | 662 | 166 | 500 |
| | Surplus | 732 | 651 | 1145 | 1536 |
| | Annual Output | 237 | 352 | 339 | 544 |
| 1979 | 4-year cumulative output | 1048 | 1590 | 1435 | 2444 |
| | Take-up | 128 | 455 | 365 | 475 |
| | Surplus | 920 | 1135 | 1070 | 1969 |
| | Annual Output | 278 | 427 | 371 | 653 |

TABLE XIV (1) Run (d)

PROJECTED GRADUATE STOCK AT WORK, ASSUMING 5.3 PERCENTAGE POINTS REDUCTION IN GROWTH-RATE OF VOLUME OF OUTPUT

| | 1975 | | 1979 | |
|---|---|---|---|---|
| Sector | Projection | This Projection | Projection | This Projection |
| 1 | 2000 | 1459 | 2065 | 1133 |
| 2 | 631 | 445 | 733 | 374 |
| 3 | 1309 | 915 | 1429 | 725 |
| 4 | 278 | 195 | 304 | 155 |
| 5 | 162 | 113 | 172 | 86 |
| 6 | 4258 | 2900 | 4577 | 2263 |
| 7 | 491 | 350 | 617 | 329 |
| 8 | 45 | 32 | 50 | 26 |
| 9 | 2612 | 1843 | 2936 | 1513 |
| 10 | 1735 | 125[illegible] | 2055 | 1088 |
| 11 | 175 | 123 | 188 | 95 |
| 12 | 258 | 180 | 279 | 141 |
| 13 | 1654 | 1113 | 1676 | 808 |
| 14 | 126 | 87 | 134 | 67 |
| 15 | 134 | 93 | 145 | 73 |
| 16 | 95 | 66 | 101 | 51 |
| 17 | 121 | 85 | 132 | 67 |
| 18 | 1224 | 897 | 1385 | 761 |
| 19 | 21 | 14 | 22 | 11 |
| 20 | 92 | 54 | 99 | 50 |
| 21 | 143 | 99 | 153 | 77 |
| 22 | 830 | 588 | 1080 | 582 |
| 23 | 121 | 89 | 137 | 69 |
| 25 | 1044 | 1105 | 1261 | 1287 |
| TOTAL | 19571 | 14114 | 21732 | 11831 |

TABLE XIV (2) Run (d)

GRADUATE OUTPUT, TAKE-UP AND EMIGRATION (Projection (d))

| Year | Quantity | Agricultural Scientists | Engineers | Medicals | Natural Scientists |
|---|---|---|---|---|---|
| 1967 | Annual Output | 172 | 240 | 283 | 378 |
| 1971 | 4-year cumulative output | 761 | 1084 | 1198 | 1697 |
| | Take-up | 525 | 888 | 840 | 814 |
| | Surplus | 236 | 196 | 358 | 883 |
| | Annual Output | 202 | 291 | 310 | 454 |
| 1975 | 4-year cumulative output | 893 | 1313 | 1313 | 2036 |
| | Take-up | - 490* | - 743* | -1025* | - 87* |
| | Surplus | 1383 | 2056 | 2336 | 2123 |
| | Annual Output | 237 | 352 | 334 | 544 |
| 1979 | 4-year cumulative output | 1048 | 1590 | 1435 | 2444 |
| | Take-up | - 264* | -365* | - 393* | 6* |
| | Surplus | 1312 | 1955 | 1827 | 2438 |
| | Annual Output | 278 | 427 | 371 | 653 |

* This implies that in a declining growth situation the market contracts, throwing people out of jobs, as well as blocking intake.

TABLE XV

GRADUATE TAKE-UP AND EMIGRATION IN THE VARIOUS PROJECTIONS, PERIOD 1971-1975, 1975-1979 (SUMMARY OF TABLES XII- XIV)

| Period | 1971-1975 | | | | 1975-1979 | | | |
|---|---|---|---|---|---|---|---|---|
| Discipline | Ag | Eng | Med | NS | Ag | Eng | Med | NS |
| 4-year cumulative output | 893 | 1313 | 1311 | 2036 | 1048 | 1590 | 1435 | 2444 |
| Projection (a) 5.3% background growth per annum | | | | | | | | |
| Take-up | 561 | 997 | 834 | 851 | 699 | 1242 | 1097 | 1045 |
| Surplus | 332 | 316 | 477 | 1185 | 349 | 348 | 338 | 1399 |
| Projection (b) 2.6% background growth per annum | | | | | | | | |
| Take-up | 17 | 238 | 22 | 372 | 120 | 395 | 320 | 442 |
| Surplus | 876 | 1075 | 1289 | 1664 | 928 | 1195 | 1115 | 2002 |
| Projection (c) expanded growth in 'R & D Sector' relative to (b) | | | | | | | | |
| Take-up | 161 | 662 | 166 | 550 | 128 | 455 | 365 | 475 |
| Surplus | 732 | 651 | 1145 | 1536 | 920 | 1135 | 1070 | 1969 |
| Projection (d) 'zero growth' situation | | | | | | | | |
| Take-up | -490 | -734 | -1025 | - 87 | - 264 | - 365 | - 393 | 6 |
| Surplus | 1383 | 2056 | 2336 | 2123 | 1312 | 1955 | 1827 | 2438 |

N.B. All growth refer to 'background'; the 'top seven' industries have growth which are treated separately as regards differential from the background.

However, there is more to this than 'course work'. The existing academic staff is not adapted to cope with industrial-oriented M.Sc. work, especially if practical project work is involved.

It will be necessary to encourage the development, among the academic staff, of the type of industrial consultancy expertise which would enable them to supervise the M.Sc. project work, and ensure that it fulfils a genuine need on the part of the industrial sponsor.

A positive role can be played in this development by the 'industrial liaison officers'; these posts, financed by the NSC, occupy key 'triple points' between those colleges which have taken them up, the Applied Research Institutes and industry.

To fix ideas, a typical one-year industrial sponsored project in the field of operations research and statistics involves financial support of about £2,000, takes up 50 per cent of the time of three students, and about one-fifth of a man-year of staff consultancy time. The latter is crucial to the industrial success of the project.

To provide effective practical projects for such re-orientation, it would be necessary to look for industrial sponsorship money for 100 such projects per year (assuming an average of three students per group-project). This amounts to a further £200,000. It would also involve 100 university staff members one day per week in consultancy/supervision work.

In 1972/73 the Institute for Industrial Research and Standards received fees for research work of £293,000. Thus we are talking of nearly doubling the money spent by Irish industry on contract or sponsored research. This is perhaps not realistic, especially as the academic staff concerned are somewhat inexperienced in their approach to industry in the majority of cases.

A better method of approach would be for the State (through the IDA or directly) to provide an earmarked subsidy to the IIRS, AFT, Foras Forbartha etc., equivalent to what they draw from the sponsored research market, and for the state applied-research body to handle the injection of project problems into the third-level system. These would be related to current work, but more long-term, possibly involving the development of a new technology ultimately to replace, or improve, the short-term solution being worked on currently by the applied research body staff.

The outcome of these sponsored group projects should ideally be the injection of one of the students concerned into the state research body (with the new developing technology) and the other two into industry, including the firm most closely related to the sponsorship.

It might be necessary to ease this process with a wage-subsidy for a year or two.

Thus the 'graduate surplus' problem appears to be soluble for less than £1m per annum in the short-run. In the long-run, it should disappear in proportion as a dynamic of technological consciousness develops in the business world, based on a web of personal contacts among those engaged in management, research and development who share common scientific experience.

There is another possible road to generating wealth with the graduate surplus. It is complementary to the one outlined above. It consists in generalising the medical experience and consciously orientating the Higher Education System to cater for the 3rd-world market.

This expansion need not be confined to undergraduate level. It could cater for the same type of post-graduate re-orientation demand as is needed on the home market.

If the 300 M.Sc. per year rate were expanded to say 400, we could take 100 graduates from abroad and train them in problem-oriented technology (oriented towards industry, agriculture or services). This process would qualify for UN or other appropriate support, and would bring in foreign exchange. It would also generate more wealth-producing jobs in the Irish 3rd-level education system.

The mutual confidence network derived from this would lead to the generation of a market in export consultancy in the countries from which the guest-students had come. There are precedents for this type of know-how export business: for example Aer Lingus, does maintenance training work in Libya, Algeria and elsewhere.

ACKNOWLEDGEMENTS

We wish to thank the IDA which sponsored the project and provided some of the input data; Professor Gordon Foster of the Department of Statistics, Trinity College, Dublin, for his encouragement, also Rory Alkin and David O'Brien who contributed to a preliminary run of this project in the course of their M.Sc. in Statistics and Operations Research.

We also wish to thank the staffs of the National Science Council, the Higher Education Authority and the Census division of the Central Statistics Office for their assistance in the supply of data.

Finally we wish to thank Mrs. Patricia Fitzpatrick and Miss Denise Jones for their help with the preparation of the typescript.

## DISCUSSION

*Dr Derek A. Scholefield:* We have to thank the authors for their detailed quantitative approach in an area of investigation which is of great importance but frought with difficulties.

We are a small country, committed to a programme of expansion of higher level education at a time in our history when we are experiencing all the pangs of a minor industrial revolution. We have the processes of growth and contraction occurring simultaneously and, super-imposed upon our own internal development, we have all the pressures of the world-wide economy which is itself being subjected to massive strains. Indeed, we are surrounded by uncertainty and our systems of education, and those being educated, inevitably must share the load.

We have to remember as we pore over the tables of statistics and follow the logic of the arguments presented by the authors that we are not dealing with items of plant, equipment or machinery, but with people, with individuals, each with his or her own life aspirations and not a mere chequer on a board to be moved at will at some late stage in the educational game without an early warning system.

You will gather from these opening words that it is not my intention to attempt any analysis of the statistical approach adopted by the authors, if indeed I felt qualified to do so. Rather do I intend to concentrate by contribution on their discussion and conclusions.

The results of this statistical approach do not really surprise me, neither would I expect them to surprise any of my colleagues who work within the Careers and Appointments Services of the Universities. The authors have generously made reference to the Graduate Placement Report of the Association of Irish University Careers and Appointments Services, the only available documentation on the Further Study or Training or Employment taken up by men and women who have qualified recently for full-time first degrees. Perhaps I could quote from my own Annual Report for the year ending 31st December 1973, in respect of graduates from University College, Dublin.

| FACULTY | TEACHER TRAINING | RESEARCH WORK OR FURTHER ACADEMIC STUDY (IRELAND) | EMPLOYMENT IN IRELAND |
|---|---|---|---|
| | % | % | % |
| Arts | 68.0 | 14.6 | 13.0 |
| Science | 42.9 | 31.0 | 25.2 |
| Agriculture | - | 45.2 | 52.3 |
| Social Science | 13.1 | 10.5 | 71.0 |
| Commerce | 17.8 | 9.2 | 72.4 |
| Engineering | - | 14.6 | 85.3 |

Quite clearly, the Science graduate appears low in the ranks of those undertaking direct employment in Ireland, though by no means as low as the Arts graduate. I have had to extend my view to include the Arts graduate because the authors say in their discussion that the problem is basically one of relative over-production of specialist scientists. Their conclusion may not be so accurate when we look at the whole pattern of third level education and remember the need for the injection into Irish industry and commerce of graduates from a wide range of academic disciplines. Clearly it is highly desirable that there should be a dramatic increase in the level of technological understanding available to Irish industry but we should need to ensure that this reaches the main stream of policy and decision-making. I am not so sure that the availability of a wider range of M.Sc. courses, even based on project work, would necessarily achieve this objective. I have to confess that some of my doubts are compounded by the proposed titles for such courses.

I think the issues involved are much wider than this paper suggests, for nowhere is reference made to the overall pattern of graduate recruitment into Irish industry and commerce and the many practical issues involved. There are problems to overcome if the approach suggested by the authors is to have any chance of success.

A major obstacle is indeed the inability of many organisations to provide satisfactory training for the graduate, irrespective of discipline, endeavouring to make the transition from study to application. This I would call the "experience barrier". The strength of the barrier does vary according to discipline. Economists, Mathematicians and Engineers may break through with relative ease. It is not so with other disciplines - including the Natural Scientists - and so the authors' proposals are a step in the right direction, not only in terms of project work but also for some system of subsidising graduate input into industry. I have been particularly encouraged by the initiative already shown by AnCO in this direction.

It seems to be a heavy burden to lay at the door of one particular Faculty to say, as the authors do, that the Science graduate, as such, is of little use to industry at this point in time. The universities would claim, and students would want them to claim, that they are not training people specifically for industry. There is little to choose in my mind between the direct usefulness of the Arts, Commerce, Social Science, Engineering and Science graduate at the end of three or four years of study. Furthermore, I am concerned at the blanket approach to the Sciences without any attempt to recognise the individuality of studies in Biochemistry, Microbiology, Computer Science, Pharmacy, Pharmacology, Physics, Chemistry, to name but a few. If we take this paper at its face value, the authors are calling for the re-orientation of some 60 per cent of our scientific graduate output, if we exclude the number of mature specialists.

But then we have to consider a second major obstacle, the "sitting tenant barrier", where the main stream of staff recruitment is non-graduate and graduate tributaries are not welcome in case they produce some predictable wave effects. The authors identify this problem but do not to my mind sufficiently emphasise that it is an on-going process and not confined to the present mature 30- or 40-year-olds. Only careful and painstaking negotiations between management, staff associations and unions in the light of changes in the availability pattern of educated people will bring progress.

Now I come to the third major obstacle, the "graduates' personal preparation barrier". Many are ill-equipped after three or four years' study, having taken little interest in college life, extra-curricular activities, current affairs, hobbies and vacation work experience. The specialist scientists referred to by the authors are no exception!

Let me now refer back to the text of the Paper before us, and the emphasis on the "re-orientation process". This makes the assumption that the graduates were orientated in the first instance. Speaking as a Careers and Appointments Officer, again I have doubts.

I do not regard young men and women in the age range of 20 to 21 as specialists in any sense of the word and, if we have to talk about re-orientating at this stage, we have to be absolutely honest with ourselves and admit that there is something radically wrong with our approach to third level education, and in the universities in particular. Indeed, something so radically wrong that it is breathtaking in its magnitude and consequences. We have not yet learned that decision-taking about careers and employment has to be a continuous process, beginning in the schools, continuing throughout the years of study at higher levels and progressing throughout life. We operate a large part of our educational system on one or two "spot checks" on our pupils and students, possibly lasting an hour at the most, as if they were factory products on a belt. Is it sufficiently widely realised that hundreds, no thousands, of young people read for degrees and diplomas with almost no chance or facilities to talk about how their studies may have some direct relevance to the world of employment? To bring it to hard reality: here in our five Irish universities there are 6½ Appointments Officers to care for the needs of some 26,000 students, while the University of Manchester alone has 10 such Officers.

If there is to be a fund of £1 million per annum to be devoted to some re-orientation process of young people aged 20 to 21, my plea would be for some 2½ per cent of that sum to expand advisory services and to ensure that the young people were less dis-orientated in the first instance!

May I claim a moment or two more to consider the position of young people making decisions about subjects to study. Hopefully, they choose these because they are interested in them, because they feel motivated to acquire knowledge in depth and because, all being well, they can learn to live with their choice. How they will apply their disciplines, and themselves, remains something of a mystery, which without continuing aid can become a traumatic experience. The appearances, the images, the behaviour of the different employment sectors condition them and resistances develop which are hard to overcome. It is an inescapable fact that in this decade industry and commerce on the world scene has no great appeal; the image is tarnished. Before there is too much talk about the re-orientation of young people, there is surely a need for a massive re-orientation of the industry into which we intend to inject them. Quite frankly, I see little evidence of leadership from industry in this direction. Without the right climate, the young graduates will not accept re-orientation. Thus the understanding has to begin earlier if young people are to make their contribution to innovation, entrepreneurial development and the whole future of Irish industry.

Our graduates face many problems as they endeavour to take their place in our national work force and make a contribution. Our society demands an extension of higher education facilities. We have still to learn how to live with our demands.

It is my pleasure to thank the authors and to congratulate them for tackling a difficult subject and providing us with a platform for discussion.

*Miss Catherine Keehan:* I have great pleasure in seconding the vote of thanks for the excellent paper delivered here this evening. The study described is not only useful in itself, it can also be seen as a contribution to manpower planning as a whole. Dr Scholefield extended his remarks to other academic disciplines. I would like to extend mine even further, and comment on manpower policy as a whole, and in particular its information needs.

In a recent report on manpower policy in Ireland, the OECD commented adversely on the manpower information currently available in this country. That report stated "the presently available manpower data are inadequate for manpower design and control."

In a report on manpower policy which will be published shortly by the National Economic and Social Council, the lack of available information is again criticized, as is the lack of coherence in manpower planning.

These criticisms cover not only the immediate areas of concern to our speakers tonight - qualified technological manpower - but virtually every other area as well, from the least to the most highly skilled workers. There is an urgent need to collect and analyse information on all aspects of manpower, - under headings such as present and future labour demand and supply, the location both in an industrial sense and in a geographical sense of job opportunities and those available to fill them, and the training needs of both industry and the labour force. I make the distinction here between training for industry and the labour force because I believe manpower planning is not merely an economic and statistical problem, it has social consequences also. We must therefore try to ensure that not only are people trained to fill jobs currently or potentially available, but that they themselves can gain optimum satisfaction and remuneration for the jobs they do.

In the last part of their paper, Dr Johnston and Mrs Franklin mention a number of alternative courses of action to cope with the problem of relative over-production of specialist scientists. To these I would like to add another. I believe that we should give youngsters,about to embark on some form of third level education, a much broader outlook on the opportunities open to them when they graduate. There are areas of skill at all sorts of levels where there are presently and will continue to be more jobs available than there are people to fill them. Perhaps if this problem was coped with at the beginning rather than at the end we might solve it more easily.

Finally I believe that a coherent and well planned manpower policy, on series of policies is vital for economic and social progress. I also believe that the most appropriate body for encouraging the necessary research is the National Manpower Service. I hope that our current economic problems will not prevent the appropriate authorities from ensuring that NMS gets all the resources it needs - both financially and otherwise, - in order for it to carry out this vital function.

*Dr. Diarmuid Murphy:* said that besides congratulating the authors of the paper, congratulations and thanks were due to the Central Statistics Office for the decision to include a question on scientific and technical qualifications in the 1971 Census of Population. The information gained from this question had been very useful and enabled manpower studies such as the present one to be carried out.

There were many technical points in the paper which he would like to raise but felt that these were best dealt with in private discussions with the authors. The fact that the paper demonstrated an over production of graduates, especially in the natural sciences, raised the need for further studies on the capacity of the economy to absorb such people. While comparison with the UK was not always valid (due to differences in population structure of the economy etc.) he felt that a comparison of the absorption of graduates in the two countries would be of interest.

Thus, comparing numbers of population per single 'scientist' (i.e. agricultural, engineering, medical or natural science) one gets the following figures:

| Field of science | Head of population per 1 'scientist' UK (1966) | Ireland (1971) |
|---|---|---|
| Agricultural sciences | 2,280 | 760 |
| Engineering and technology | 154 | 484 |
| Medical sciences | 99 | 400 |
| Natural sciences | 348 | 704 |

(*Sources: Sample Census 1966 Qualified Manpower Tables (UK); Census of Population of Ireland, 1970, Bulletin No. 40)*

It appears therefore, that there might be considerable leeway in the Irish economy to absorb more graduates. Comparison with countries whose economies were more similar in size to Ireland should give interesting results.

*Mrs Monica Nevin:* I have listened with great interest to Dr. Johnston's and Mrs. Franklin's paper and there are one or two points I should like to make.

The authors speak of the rapid expansion in recent years of the number of natural scientists. In fact, over the past decade the number of science graduates has remained remarkably stable; in 1964 the number graduating from University College, Dublin with a science degree was 175, in 1974 the number was 170. Similarly the number of postgraduate science students has varied little in the period 1969-1974. There is, I know, a table in the recent HEA Progress Report showing changes in student numbers, in university faculties, over the period 1968-1974. In this table the percentage increase for science is given as 28 but a note below the table cautions that this percentage rate is inflated by internal changes in course arrangements in University College, Cork where, from 1973 on, entrants to Medicine, Dentistry and Dairy Science must follow, in First Year, a common foundation course with science entrants. Furthermore, when speaking of science students we must remember that Trinity College includes students of Psychology and of Geography in the Faculty of Science and that in University College Dublin, Pharmacy students are so listed, although after First Year, Pharmacy students pass out of pure science. However, I ought to say that in the current academic session, 1974-75, the number of entrants to the Faculty of Science in University College, Dublin has risen to 332. We shall have to wait one or two years to know whether this is a genuine increase or merely a statistical fluctuation. During the period 1965-66 to 1973-74 the number of science entrants varied between a maximum of 308 (1966-67) and a minimum of 248 (1971-72).

Above all, I should like to stress that a degree in the natural sciences is neither a specialist nor a professional qualification. The idea that a science graduate must follow a career where he uses his scientific knowledge *directly* is outmoded. A university course in science is not a "training" for vocational employment, it is an education preparing the way for many possible careers. In the years to come we are likely to see science graduates entering in increasing numbers the professions of law and accountancy and seeking employment in banking, management and in the non-scientific government service. Being a physicist himself Dr. Johnston will be aware of the wide spectrum of jobs held already by physicists. I need only remind him that the Chief Executive of Aer Lingus is an honours physics graduate as is the Irish Provincial of the Jesuits.

It may be of interest to note that there exists for postgraduate science students in University College Dublin, a voluntary course in the principles of Finance and Management organised by the Department of Business Administration, attendance at which lies in the range

24 to 30.

Finally, I should like to emphasise that the links between the universities and the outside world on which they depend must not prevent the universities from carrying out their main function which is to offer not merely specialist or technical training but a full and true education. There is, furthermore, a vital need to maintain a close contact between research and univeristy education. The universities are the source of fundamental ideas, ideas which often determine the speed of change and growth in industry.

*Dr. R.C Geary (with some afterthought)* I agree with Mrs Nevin that the universities, of their nature and monkish origin, are basically temples of pure thought, dedicated to the training of the minds of students, however this training may be applied in their later careers. Technical schools have, on a large scale, got themselves grafted to universities, mainly no doubt for reasons of overhead economy, if also to civilise technicians by association in their formative years with practitioners of traditional university disciplines, that "pale cast of thought". I would have wished that the authors had dealt with that largest body of graduates who find, and usually make a success of, jobs not necessarily related to the discipline which they followed in the university.

Everything everywhere is changing rapidly in the general direction of every activity becoming more technical, so, in the interest of their careers as a whole, science students should train in a second discipline closely associated with running an enterprise. In the past, specialisation in science has proved a promotional dead-end and the better the scientist at his job the deader the end: the big jobs went to accountants and generalists. I recall a conversation long ago with my eminent friend, Dr. J.P. Beddy, about what we would do with our sons, Jim's remarking "Chartered accountants always do well, when business is booming, yes indeed, or when it is bankrupt there are always receiverships".

I have not had time to study the methodology of the authors in making their forecasts. Might I ask, for immediate reply, if this method could be described as a very elaborate series of proportionalities? (Dr. Johnston: Yes).

I have been savaged in the past for being allegedly pro-emigration. Certainly I have written that the Irish race is many times more prosperous than, equally numerous, it would have been if we all were forced to stay at home. A deplorable feature of Irish emigration in the past was that the vast majority were unskilled. Nowadays every scientific graduate should contemplate sojourns abroad as good for his life-style, experience and pocket. In reverse, we should welcome foreign skills. It would be grossly wasteful for a small country to try to develop all the very specialised skills it may require in small degree and from time to time unless the training was also for export. At the beginning of third level education, every young person should contemplate working abroad for short or long periods. A country may be too small for a large talent. This country could and should give third level training to students in excess of its own needs.

I would have wished that the authors had specifically allowed for this emigration aspect. It requires discussion also, including that old oversimplified argument that, because a graduate costs £x to rear and educate, the country loses £x if he emigrates. I refuted that fallacy long ago in these halls. I admit that under modern conditions it requires reconsideration.

*Mr. D. Montgomery:* stated that while he had been unhappy about some parts of Dr. Johnston's paper, he shared Dr. Johnston's basic worries about the situation. He felt that some other speakers from the floor had been slightly complacent about the problems facing our science graduates. He stressed the fact that because of unemployment and financial restrictions in many countries, it was becoming more difficult each year for Irish graduates to obtain research awards or employment abroad. We could no longer rely on training provided by foreign countries. He agreed with

Dr. Johnston that there was a need for more 'problem-oriented' courses to be offered at post-graduate level in this country and he offered the opinion that perhaps too often the impression was given that research was the only suitable career for good science students.

*Mr P.S. McMenamin:* I would like to concentrate my remarks on some implications of Dr Johnston's and Mrs Franklin's excellent paper for the industrial development drive.

At the present stage in the development of our economy, industry is still the primary and principal generator of growth. Thus, about 230,000 or 20 per cent of our labour force is now engaged in manufacturing industry. Manufacturing exports last year were close to two-thirds of total exports.

If we are to increase the rate of growth of manufacturing industry to that needed for the creation of the 20,000 new non-agricultural jobs required each year to achieve a State of full employment in the 1980s, a number of key features will need to be present. Amongst these will be a labour force possessing the disciplines and skills required by modern industry which is tending to become more and more technical.

For this reason from the purely practical point of view, the paper which has been presented is and will be very valuable to those who have to engage in discussions with industrialists contemplating the establishment or expansion of activities requiring graduate technical personnel. It is and will, also, be useful in pinpointing the type of employment that should be provided to make the fullest use of the output of part of our educational system. The findings, therefore, are of help in the selection of the types of industry from abroad that desirably should be encouraged by the IDA to establish plants here.

Indeed, from these points of view the value of the paper could be even increased if the model could be re-run with the inclusion of firmer or perhaps more up-to-date forecasts of sectoral output growth rates thus improving the precision of the projection of the demand/supply relationships. The figures originally supplied by the IDA, though as accurate as we could make them, were supplied purely as necessary inputs to allow the model to be operated.

I mentioned earlier that it is estimated that about 20,000 new non-agricultural jobs need to be created each year if we are to achieve full employment early in the next decade. The present manpower exercise has dealt with a small, albeit important, proportion of these jobs. We would hope that the present paper will only be the first instalment of an extensive investigation of a most important subject.

*Professor B.M. Walsh:* I would like to add my congratulations to those already offered the authors on their stimulating paper.

One topic that seems to me to have been neglected in tonight's discussion is the question of the financing of higher education. The over-production of certain types of graduates is an issue for public concern because most of the cost of training them is being borne by the tax-payer. If the graduate becomes successfully employed in Ireland, his or her income is appreciably enhanced by this investment of public funds. If the graduate remains unemployed or emigrates, then there is no return within the State to the investment of public funds in this person. Either way it is questionable whether the heavy reliance on direct State grants to higher education and to students is the optimal manner of financing the system. If students had to resort to loans, perhaps repayable on more favourable terms for those who remain in Ireland, the output from the universities might come more into line with the economically justifiable level.

Of course this reform might entail a fall in the output of higher level students. But we should avoid the assumption, at times implicit in this paper, that public funds should be spent on scientific training because it is of itself a good thing. If the market for qualified manpower in

Ireland suggests that there is a higher return to further investment in, for example, legal training or in turning out business school graduates than in maintaining the level of investment in scientific education, then we should advocate switching some of the State budget from the latter to the former, even if we regard scientific degrees as inherently "purer" or "better" than legal or business training. The case for heavy subsidies to scientific training, and to employers to absorb scientists in larger numbers than they are willing to at present, is based on a model of economic growth and technical change that is not made explicit in this paper. In fact, the only justification for such subsidies advanced in the paper is the reference to the Cooper-Wheelan study. This is a complex issue, and one where there is room for disagreement with the rather strong assumptions about the beneficial externalities generated by investment in scientific training embodied in the present paper.

*Mr A P. O'Reilly* I think the authors should be congratulated, not just for their interesting paper, but for helping to attract attention to the importance of, and the need for, manpower planning at national level. Manpower planning should, however, go further than considerations of supply and demand - it must, for example, take account of manpower utilisation and effectiveness. Work in which I am currently involved shows that there is considerable misutilisation and underutilisation of scientific talent in Ireland - misutilisation in the sense of scientists working in fields other than that in which they have been trained, and underutilisation where they are forced to work at sub-professional level. There is also significant evidence that the effectiveness of many scientists is suffering, due largely to the inadequacy - in quantity and quality - of technical support staff.

In reference to some of the earlier remarks in this discussion I would suggest that the university/employment (public as well as private) interface leaves much to be desired in the whole area of fitting graduates to jobs and jobs to graduates. The graduate who finds that his biggest difficulties in employment have to do with dealing with people and putting his thoughts on paper must get little consolation from the endless academic argument about whose responsibility it is to help him cope with those and similar problems.

While I am in general agreement with much of what Miss Keehan has said, I wonder if she is fully aware of, for example, the importance AnCO attaches to the social dimension of its responsibilities, and what it is currently doing to meet those responsibilities?

*Dr Johnston:* May I thank the many contributors to this discussion for their many kind words, and also for their critical ones. In reply to Derek Scholefield: I agreed that a desirable goal is to get people who have a scientific understanding of technology into key policy decision-making positions. I suggest that the provision of more industrial-sponsored masters degree projects, although not a sufficient condition for the achievement of this goal, represents a necessary first step. The proposed titles constitute a small sample of the possible, rather than a definitive listing. The role of the sponsored masters degree project is to help a student over Dr Scholefield's 'experience barrier'.

The blanket approach to the sciences is I agree highly unsatsifactory; there is however nothing to prevent the existing methodology from being re-run with the main-stream of available data on as refined a set of sub-disciplines as you like. The limit is the census coding of the qualifications. The 'inner stream' of R & D manpower data, however, could not be refined without disaggregating Dr Murphy's R & D survey material.

I would agree whole-heartedly with Dr Scholefield in his plea to spend money on careers advisory services at entry to the 3rd level system. This point was also touched upon by Catherine Keehan. This however is not a total solution. The honours specialist degree courses, if they are to provide their quota of brilliant scientific innovators capable of advancing the frontiers of human knowledge, will have to over-produce by a factor of two or three above the needs of the academic and basic research system. It is with the fate of these drop outs from the basic scientific research system (in whose number I count myself) that I am concerned. I personally had to go through a somewhat painful re-orientation period. I would like my successors to be helped over the obstacles, to be inducted across the cultural gap.

I would like to thank Dr Diarmuid Murphy for contributing the UK comparison, in terms of head of population per science-technology graduate. We have a factor of three to make up for engineers, while there is only a factor of two for scientists. The absolute level of the factor is related to the degree of development of the economy; one would expect it to be different as between the two economies. I would prefer to conclude from these ratios that our science-engineering ratio is pathological, and to suggest that our relative over-abundance of scientists and scarcity of engineers is a consequence of a pathological academic bias in the second-level system.

I accept Monica Nevin's statement that the definition of what constitutes a 'scientist' may introduce spurious apparent trends. However, although I referred in the unrevised text to a 'rapid expansion' of natural scientists in recent years, even if the numbers are stable I don't think my argument fails, as it is based on the high absolute level of science graduate production relative to (a) engineers and (b) intake of science graduates into the working population.

I am not advocating that an honours specialist degree holder should remain a specialist for his working lifetime. Although, as Mrs Nevin says, this idea is outmoded, and courses in management etc. are being introduced into the science faculties, the transition from specialist or technique-oriented modes of thinking to generalist or problem-oriented is still difficult for most young graduates, requiring a dose of relevant experience, possibly condensed into some sort of apprenticeship scheme, which I am convinced can be combined readily with a masters degree in a relevant technology.

Leaving aside Dr Geary's apparent failure to distinguish between the Irish nation (which exists, although somewhat tenuously) and the Irish race (which does not), I feel I must come back on the question of the cost of a graduate emigrant. Dr Geary holds that it is fallacious to budget him negatively at the cost of his rearing and education. I would tend instead to budget him at the discounted value of his future production: not just earnings, total value produced, including the discounted value of the marginal production attributable throughout the economy to the innovations he might have produced if absorbed at home. I hesitate to attempt to quantify this snowball-effect but I know it must exist, and the process is a proper subject for further scientific study.

Regarding the utility of this work to the IDA, who financed it, and to whom I wish to convey thanks and appreciation, may I stress the need for closer and more specific analysis; although there is an abundance of 'scientists' we are weak, for example, in metallurgists. I must stress the need for the closest possible co-operation between the IDA and the third-level system, extending perhaps to the establishment with IDA support of high-technology enterprises on the fringes of the colleges, on the pattern common in the US but now spreading to the UK, in places such as Herriott-Watt and Cambridge.

In conclusion, may I say that I look forward to the development of some centre of continuity of manpower planning effort in the Republic, into which the momentum of the present study could be directed.