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SWITCHING BETWEEN ACADEMIC DISCIPLINES IN UNIVERSITIES IN THE NETHERLANDS

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The Netherlands university system encompasses roughly one half of the state financed research enterprise. Some characteristics and data on the field of education and present occupation of the professional staff in this system are given and conclusions are drawn concerning field mobility and mutual influencing of different disciplines.

Introduction

Considerable interest was attributed in the last decades to the geographical mobility of scientists and its implications. Parts of this process received the well known class name "brain drain". Another aspect that has been studied quite often in recent years is the mobility of scientists within their disciplines along career lines and their movements from one institute to another. The importance of the mobility process has for example been indicated by *Fisch*[1] "... mobility is an important stimulus to innovation since the movement of a knowledgeable individual from one organization to another is perhaps the most efficient way of transferring knowledge". A fairly complete bibliography of mobility in science has been compiled by *Vlachý* in this Journal.[2]

Much less attention has been given to the phenomenon of knowledge transfer from one scientific discipline to another. This process can be studied in part by the jumps scientists make over the borderlines of scientific specialties, usually referred to as "field mobility". Out of the 620 entries in *Vlachý*'s bibliography only around 10 papers deal with this third class of mobility phenomena.

This is a surprisingly small amount as field migration seems to be correlated with quality in scientific achievements and with the emergence of new disciplines and specialties. The reason for this lack of attention is most likely the difficulty in the definition of field, discipline or specialty. It is much easier to determine unambiguously the transition of a scientist from one laboratory to another or from one country to another than to agree upon his change of interest, especially when one tries to describe processes in the whole of the science community rather than to write some individual's biography. (See also Discussion section of the present paper.) Recently *Vlachý*[10] studied field mobility in Czechoslovakian physics related institutes.

The variety of specialties in- and outbound in his sample was much narrower than the total spectrum we are interested in. In the same paper he refers to a number of other studies which are also limited as to the variety of the specialties covered.

We have approached this problem empirically, making use of some peculiar conditions prevailing in this country. It is not the place here to discuss the validity of the statistics and the assumptions underlying our analysis insofar as they were made by others, especially by government officials dealing with science and educational policy. They are summarized in the next paragraph. For our purposes it is enough to judge them sufficiently valid not to upset the results and conclusions of the present work.

Circumstances and available data

The Netherlands spends roughly 2.5% of the Gross National Product on research. Half of that is done by the government. Again half of that effort is due to research carried out in universities. This exceptional large fraction has historical roots and is effected by a favorable staff/student ratio and relatively abundant funds for assistance and equipment. As virtually all of this is financed through block grants to the universities as a whole, very little was known about the actual costs of research vis a vis those of teaching and other activities. To gain more insight into this matter the government's Central Bureau of Statistics (CBS) carried out an investigation on the whereabouts of the academic staff of the universities and the distribution of their working time over several activities. The results of these investigations were published in two reports.[3,4] They show that virtually all academic staff at the time, except a few engaged in administration, took part in teaching as well as in research activities, although there were of course differences between individuals. This result permits us to look at the total population of academic personnel in the universities, excluding administrators, as a group of active research workers.* The CBS study lists for every individual the academic specialty in which

*The word 'scientist' is avoided, because the group includes the arts and humanities.

he obtained his masters degree equivalent** as well as the academic department he or she is working in at present. The original publications did not give a complete or detailed enough matrix of field of education versus field of occupation, but the CBS provided us with additional unpublished material for the purpose of this study, to complete the picture. Separate data were available for the academic staff as a whole and for the subgroup of the two highest ranks (full professor and associate professor equivalent*). The raw data are published in Ref.[5]

Size of the system

In order to draw a picture of the field mobility of this group it is necessary to have an idea of the size of the different parts in the system. Accurate data were lacking, but this could be overcome by the use of numbers of students who graduated in a 25 year period. These figures allowed us to make fairly good estimates of the total number of active university trained people in the different subfields in the Netherlands. The original figures were prepared especially for us by the CBS. They are listed in Ref.[5] Here we present them only graphically in Fig. 1. Multiplication of these numbers by 1.15 gives a fair approximation of the active professionals in the country in 1970–71. It is clear that the different subfields do differ quite appreciably in size. This of course has a definite impact on the internal organization and especially on the internal homogeneity of the various subfields.

Academicity

When considering a special group such as the professional staff of the universities, one wonders immediately about the representativity for the academic population** at large. Reliable data on the latter are not available. The last census could provide these figures but unfortunately the results are not yet available in sufficient detail. However, a rather accurate estimate can be made as was mentioned in the former section. The outcome thereof can be compared with the staff number attached to the different academic departments, which is done in

**The Dutch system blesses its subscribers with the doctorandus (drs) degree, roughly equivalent with the 'masters' in the Anglo Saxon tradition. The recipients have participated in some kind of research in the field in which they receive their title.

*Associate professors bear the name of "lector".

**Inhabitants of the country with a university degree equivalent to M.Sc. or Ph.D.

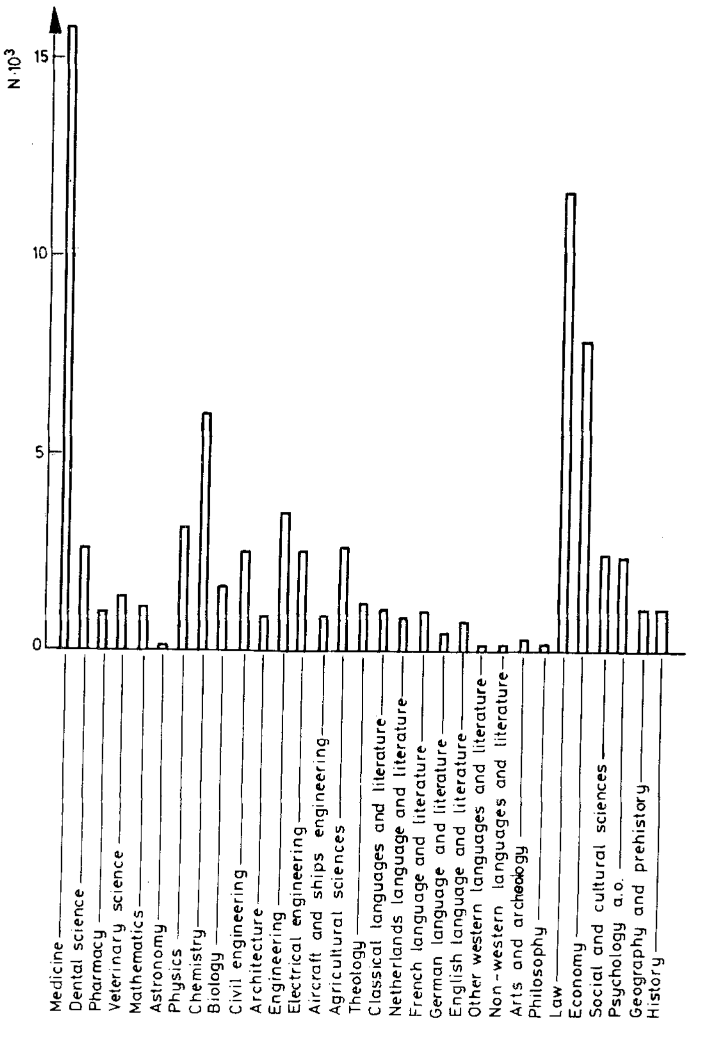

Fig. 1. Graduates (Masters degree) from universities and technical universities in the period September 1945 – March 1970

Fig. 2. It shows that our sample may certainly not be considered as a representative selection of the academic population in the country. The field mobility picture that we shall draw in the next sections therefore may not be generalized. In an American study[6] done in 1973, nation-wide data were obtained. For this reason these data cannot be compared with ours. The NRC report also uses a dif-

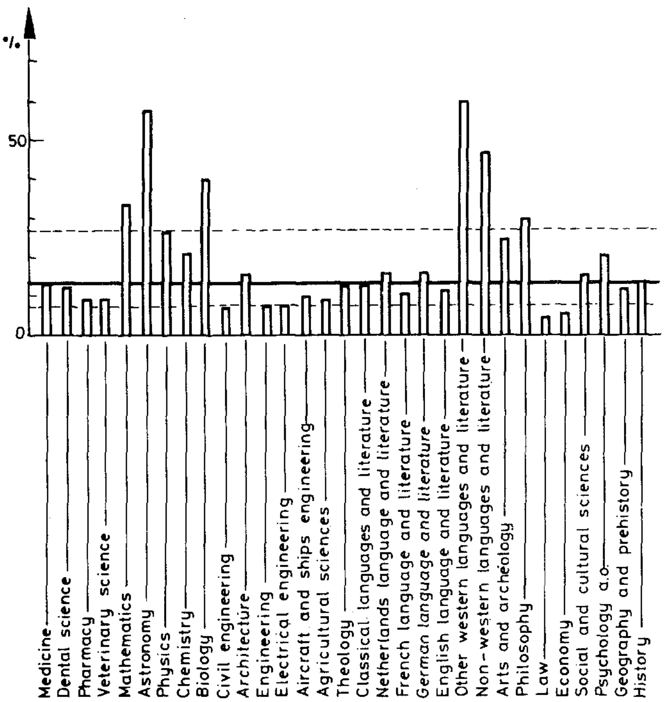

Fig. 2. Percentage of academics engaged in different departments of the universities related to total number of graduates in the corresponding fields in the country. The drawn line indicates the overall average >13%

ferent definition for the various fields. We tried to make as much of a specialty breakdown as the academic departments did allow us. In the NRC report, on one hand a division was made between 8 major fields, while at the same time a mobility picture was given within these major fields, using a subdivision which for instance for psychology and for mathematics alone uses 13 and 11 different subcategories.

We have indicated with dashed lines the levels where the academicity of subfields falls between twice and half the average value. We define academicity as the ratio between university graduates of a certain kind employed by the universities and the total of that kind in the country. There are several reasons why a subfield may be more or less academic than others. A recent growth in student numbers may have led to a corresponding staff growth without consequences for the population of that category as such. The university acts as a self-consumer. This is probably the case in biology, a field having experienced a substantial growth during the sixties. The adaption of the system to growth in the student body is much faster than to decline, due to national regulations on tenure. Since the beginning of the seventies the overall growth of the system has come to an end. Therefore the situation presented in this paper may persist for quite a number of years without appreciable alterations. Research in astronomy and mathematics is virtually only done in connection with university teaching.* The same is true for philosophy. The exceptional case of the non-usual languages may have different roots. A small country may be willing to keep a stock of specialists for strategic reasons. Those involved may occasionally serve the government but without full time obligations. The university is a good place to 'store' them.

Field mobility

In order to describe mobility of research workers in universities we look at the field of study in which they obtained their masters degree and at their present occupation. In concurrence with the definitions used by the NRC we call someone

– a *retainer or non-switcher* if both are identical;

– a *switcher* if in general the two are nonidentical;

– an *outbound* mathematician somebody who studied mathematics and is presently working in some other university department;

– an *inbound* mathematician somebody working in a mathematics department, who studied a different specialty.

With these definitions in mind we can draw a picture representing the overall field mobility in a way similar to that of the NRC study (Fig. 3). It shows that a number of fields are predominantly donors like: pharmacy, physics, chemistry, biology, classical languages and literature, Netherlands and German language and literature, geography and prehistory and history. Others are mainly receptors like: medicine, agricultural sciences, theology, western and nonwestern languages, archeology and arts, philosophy and social and cultural sciences. In other fields there is more equilibrium or the fractions are small. In the USA physical sciences (mainly physics and chemistry) were the big donors as well. (A factor 2 difference between in and out.)

A different way of looking at the mobility is a comparison between the absolute numbers of outbound research workers. This is done in Fig. 4. This picture shows the numerical domination in the field mobility pattern by physics, chemistry and biology. The chemists lead by far. A remarkable change occurs if one

*There are some research institutes outside the universities but they maintain strong links via shared staff positions etc.

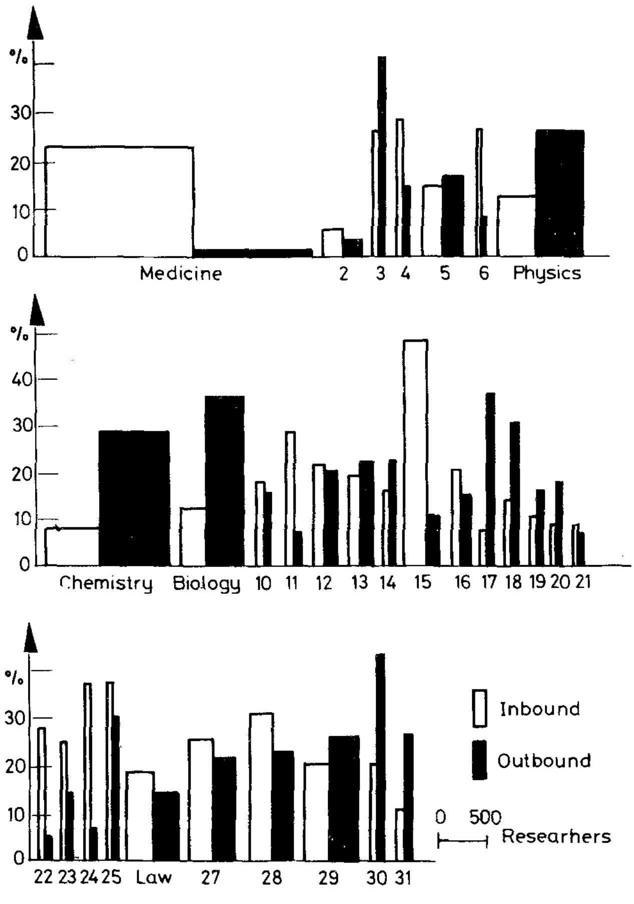

Fig. 3. Field mobility. Vertically the fraction of the total number working in a certain department (horizontally) that are inbound, resp., the fraction of the total number with a certain education in the system (horizontally) that are outbound (towards other fields). The areas are therefore proportional to the number of switchers into and out of the field, resp. 2 – dental science; 3 – pharmacy; 4 – veterinary science; 5 – mathematics; 6 – astronomy; 10 – civil engineering; 11 – architecture; 12 – engineering; 13 – electrical engineering; 14 – aircraft and ships engineering; 15 – agricultural sciences; 16 – theology; 17 – classical languages and literature; 18 – Netherlands language and lit.; 19 – French idem; 20 – German idem.; 21 – English idem; 22 – other western idem; 23 – non-western ibid.; 24 – arts and archeology; 25 – philosophy; 27 – economy; 28 – social and cultural sciences; 29 – psychology a.o.; 30 – geography and prehistory; 31 – history

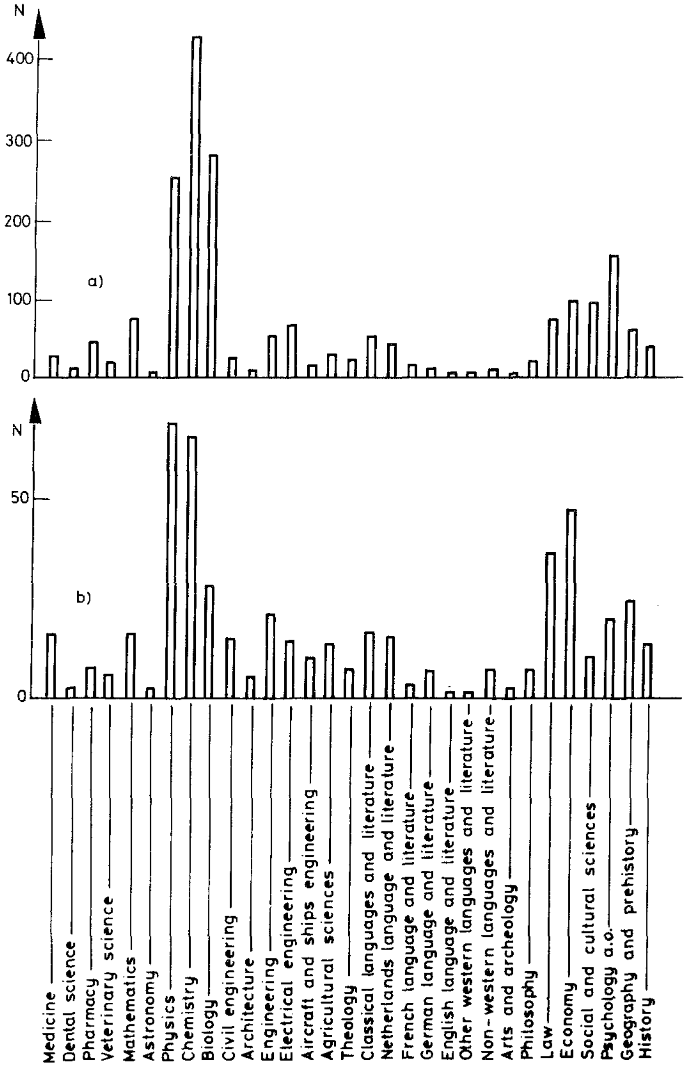

Fig. 4. Switchers outbound. (a) – all research workers; (b) – professorial ranks only

considers only the mobility pattern of the topmost research workers, i.e. the professorial ranks. It shows that physics here leads with a small margin over chemistry, whereas biology is now reduced to a significantly less mobile group. It is interesting to note the relative rise of law and economy in this group due to the transfer of these scholars to various schools of engineering, mainly.

Interdisciplinary scientific merit

A scientific discipline that sheds light on neighbouring fields and helps to understand fundamental problems in those fields certainly deserves a certain merit.* For that reason it is of interest to make a comparison between the field mobility of research workers trained in different specialties.

There are many ways one could try to compare the different fields. We have done several[5] and three were selected to be presented here. From the last section one could already obtain a measure for the size of the number of switchers. But obviously there is a catch. In 'Discussion' we shall discuss our findings and the pitfalls one could be caught in when using the raw data. The division between the fields which we chose, was an arbitrary one, simply the division the universities use for mainly administrative or teaching purposes. Therefore if field mobility is to be seen as a merit indicator it should not be too closely affiliated with only one or two neighbouring fields. Thus the first characteristic, apart from sheer numbers to look at, is the proportion of switchers in various fields. Data are given in Fig. 5. We see that outbound specialists are found in a majority of cases over more than 30% of the listed fields. Mathematicians are found in slightly more than 60% of the fields while physicists, chemists and people with legal training are found in more than 50% of the departments. The picture undergoes a significant change if one looks at the topranks only. Only physicists and chemists contribute between 40–50% of the cases as leaders in the research and teaching staff.

A third way of comparing the contribution of a specialty to other fields through field mobility of people would be the relative contribution to other fields a specialty makes. We shall define this quantity as follows:

$$RC_i = \sum_{j \neq i}^{35^{**}} a_{i,j} \Bigg/ \left(\sum_{i,j}^{35} a_{i,j} - a_{i,i} \right)$$

where RC_i – the relative contribution of specialty i to other fields,
$a_{i,j}$ – the matrix element representing the switchers out of field i into field j,
$a_{i,i}$ – the number of retainers of field i.

*In his classical paper on choices in science policy *Weinberg*[7] states: "that field has the most scientific merit which contributes most heavily to and illuminates most brightly its neighboring scientific disciplines". Although this statement has been criticized[8,9] because of the omission of other internal merit criteria, we think that in a more limited sense of using this criterion as one of several yardsticks it is undisputable.

**Some categories are not listed in this paper because of their inhomogeneous character.

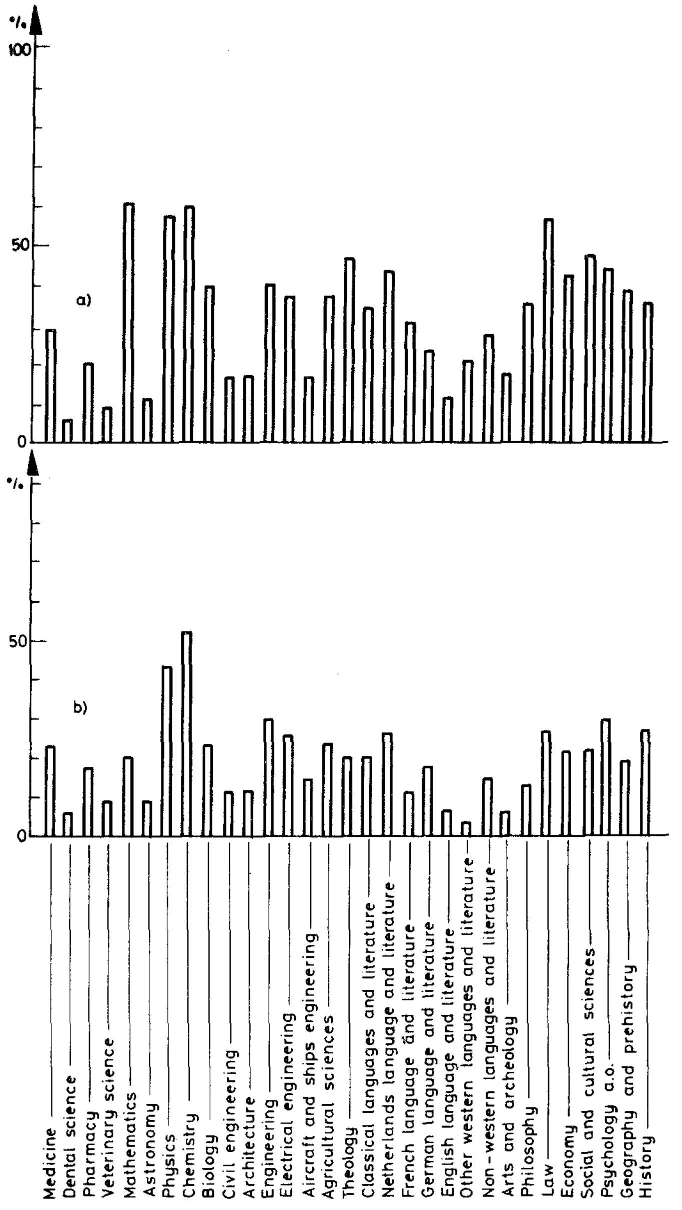

Fig. 5. Spread of switchers from each speciality over the others; (a) – all academic personnel; (b) – professors and associate professors only

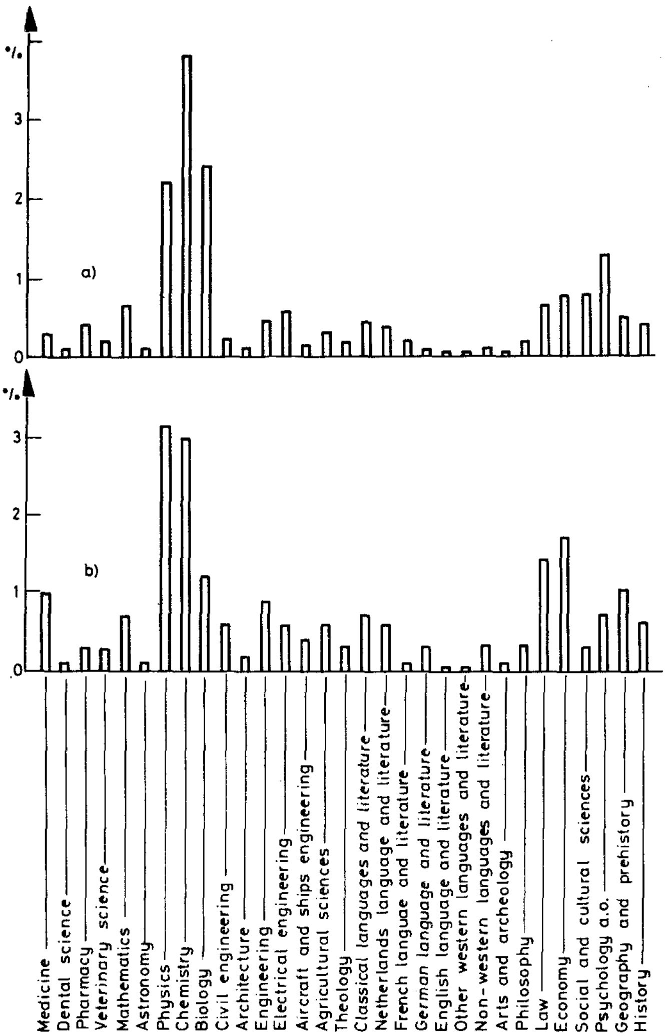

Fig. 6. The relative contribution of a specialty to all other; (a) – all academic personnel; (b) – professors and associate professors

Again here we distinguish between the whole sample and the professorial ranks. And again we see the dominant role played by physicists and chemists, while also biology appears to be among the prominent donors. When only the professorial staff is considered we note the leading position of physics and chemistry only.

A final way of comparison we would like to suggest is a look at the (comparative) Interscientific Merit Parameter, IMP, calculated for the professorial ranks, shown here, which we define as:

$$IMP_i = \frac{1}{N_i} \sum_{j \neq i}^{31} \left(a_{i,j} \Big/ \sum_{i=1}^{31} a_{i,j} \right)$$

The matrix elements represent the same as in the RC_i-formula; N_i stands for the numbers of students that graduated in that specialty between 1945 and 1970 (Fig. 1). This normalization factor corrects for the effect due to random distribution of scholars. (The larger a group, the larger the probability to meet a representant at a given place.) Moreover this definition limits to some extent the merit attributed to mobility between a few specialties only (see Discussion). The result for our comparisons is given in Fig. 7. We selected the professorial ranks for this purpose only, because appointments in this category rely much more heavily on the research ability of the persons involved than do other appointments.

It shows that some languages, arts and philosophy have an outstanding value on this scale. The only other exceptional case is that of physics. We must assume a certain random noise in the field switching process. There may be so many reasons for a person to switch that an indication of the significance of the given numbers is required. If we assume that the distribution of the stochastic parameter is not too far from Poisson or Gauss distributions, $1/\sqrt{n}$, n being the number of switchers, gives an indication for the relative error. This region is indicated with error bars in Fig. 7. In the case of philosophy $n = 7$, in nonwestern languages $n = 7$, in German $n = 6$, in Netherlands $n = 15$, in classical languages $n = 16$ and in the case of physics $n = 69$. It is this field that we feel the result of the top seven to be the most convincing.

Discussion of the results

In our introduction we pledged our allegiance to the importance of field migration without bothering too much about definitions, of what 'field', 'discipline' or 'specialty' exactly mean. This neglect may be attributed to the way we obtained our empirical material. In fact we had no possibility to shift the numbers by variations in our definitions. The material was unequivocally linked to an existing

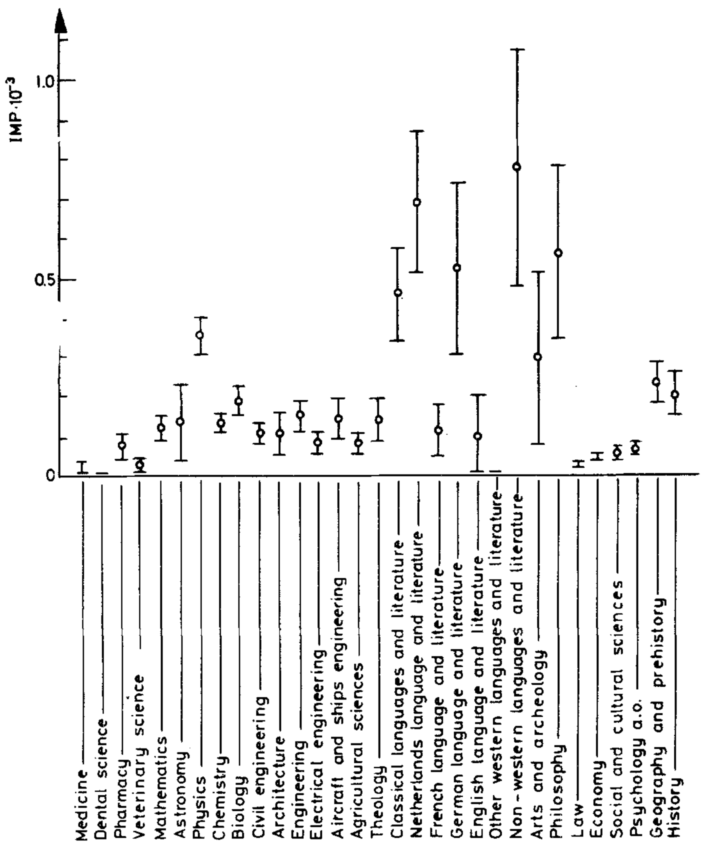

Fig. 7. Comparative Intenscientific Merit Parameter of the 31 specialities

situation: the administrative division of university departments. The problems, however, do exist. First of all there is the *inhomogeneity* of the specialties as we used them. Next there are the *'improper switchers'* and finally the *'improper retainers'*. We shall try to illustrate these general categories.

In physics for instance there are several branches. Let us consider plasma physics and nuclear physics. The first deals with collective phenomena of ionised particles, the behavior in electric and magnetic fields of a gas-like substance at very high temperatures. Most of nuclear physics, however, is studied with the aid of accelerators in which single particles are given a high velocity and are made to collide with other single nuclei. Both theory and experimental set-up of these two sciences differ appreciably. In this study the scientists doing this work have been given the same name: physicists. Now in the electronics engineering department of one of the technical universities an appreciable activity exists in MHD-conversion, a perhaps practical method to extract useful energy from a plasma. A plasma physicist moving from a plasma physics laboratory into this work may continue to do the same work as he used to. Nevertheless he is listed as a switcher, while an imaginary colleague switching to the field of nuclear physics is listed as a retainer. This inhomogeneity of fields as well as the improper counting of switchers and retainers is a disturbing factor in rough measurements like the present one. In the NRC study[6] attempts were made to estimate the influence on the results caused by these problems. It was found that 15–20% of the switchers were in fact retainers and vice versa. It was therefore concluded that the results of the investigation were not seriously affected. We have no indication of how serious these disturbing facts are in our study. At present we are studying the outbound physicists in more detail and we may be able to throw some light on this problem before long, at least for this category.

The problem may vary quite a bit from one category to the other. For instance we have the impression that general linguistic studies in the group of 'other linguistic studies' – not listed – relates to many studies in the language department as theoretical physics does to experimental physics. In the first case a switcher contributes to the field mobility, in the latter he does not. Biochemistry is practiced as a field of its own in chemistry, biology, medical and agricultural departments. All these considerations mean that not too much absolute value should be attributed to the results of the present studies.

On the other hand, present day science policy arguments quite often make use of the same ill-defined categories, when statements about the lack of interdisciplinarity in academic programs are made. The switchers show that there is a non negligible fraction of academics that do find ways to make themselves valuable in other fields.

One more serious criticism against the meaning of the interscientific merit of the different fields in this study relates to the following opposing theoretical possibilities. An imaginative outbound X-ist may fertilise a non-active group of Y-ists. Or a weak outbound X-ist, who is not welcome in his own field, may seek refuge in a fast growing – many open positions – Y-field. In the latter case the switching may be to the disadvantage of field Y. In the period over which the CBS-observations were made, there were numerous open positions in the university as well as in society at large in all fields. On the other hand in all departments the retainers formed by far the majority in each department and it is this group that makes the decisions about hiring a certain person. Thus we believe that the case of a switcher in general is one in which a positive expectation about the possible contribution to the receptor field by the donor field has prevailed. Our further study on the detailed situation of the outbound physicists hopefully will throw some light on this assumption as well as on the actual results of the switching in retrospect. More considerations on possible doubts and criticisms have been given elsewhere.[5]

In conclusion we would like to stress that more studies on the field mobility phenomenon should be done. There are strong indications that this process gives high correlations with the emergence of new specialties and even new fields, while incidental cases also indicate that perhaps interesting links exist between high quality research and field switchers.

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