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THE RELATIONSHIPS BETWEEN AGE, MOBILITY AND SCIENTIFIC PRODUCTIVITY. PART I.

EFFECT OF MOBILITY ON PRODUCTIVITY

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The main aim of this study is to estimate to what extent the productivity of researchers is influenced by their mobility. Based on emperical data of Dutch scientists it is shown that job mobility is a characteristic of productive scientists rather than a means to enhance productivity. Field mobility appears to stimulate productivity in the long run.

Introduction

Generally speaking, two kinds of mobility can be discerned: job mobility (a switch from one job to another) and field mobility (a switch from one research field to another; such a switch can but does not necessarily have to be combined with a job switch). Indications of effects of job mobility on scientific productivity have so far only tentatively been provided by a study of *Crowley* and *Chubin.*[1] They observed that amongst sociologists those who showed highest mobility scored lowest in productivity. Most probably this is not an indication for a negative effect of job mobility on productivity; most likely it illustrates the fact that the more competent sociologists acquire tenured positions, leaving the temporary jobs for the less competent researchers.

Field mobility has received somewhat more attention in empirical studies, though until now only circumstantial evidence has been presented for its effect on productivity. *Pelz* and *Andrews*[2] and *Garvey* and *Tomita*[3] observed that the more competent scientists generally were those who changed their field of research more than once. In line with this observation, *Allen*[4] concluded that outstanding scientists tended to have more contacts with scientists operating in non-related fields of research.

The interpretation of the data presented is not without its problems. Causal order has generally not been established. Contrary to common view any correlation could

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easily be explained by the fact that the changing of research field is a characteristic of good scientists and does not in itself create better researchers.

As the studies mentioned have failed to tackle this problem explicitly, the aim of our study is to investigate the causal order in the relationship between mobility and productivity.

Data and model

The data analysed

Our empirical data were collected by means of a questionaire sent to 980 researchers. These researchers were selected from the total population of research scientists employed in the departments of physics, chemistry and economics at Dutch universities. The selection was not random: a bias was introduced to ensure sufficient numbers of scientist in all age-categories and in the category of mobile scientists. This bias does not distort our empirical analysis since we are concerned with estimating the relationships between age, mobility and productivity and not with establishing the average age, mobility or productivity of scientists.

The response rate differed only slightly between different universities.* It was identical for the age groups and for the three disciplines (45%). However, a dependancy on productivity level was observed: non-respondents had published significantly less than respondents (checked on data available in the *Science Citation Index*). This in itself is an interesting observation, however, it does not disturb our empirical analysis because we examined the relations separately for researchers of different productivity levels.

Respondents were asked to provide us with data such as: age, different positions during their careers (were they involved with supervision, actual benchwork or both), the kind of research carried out (fundamental, applied or both), the time available for research over the different years, and, finally, their publication lists. These lists were used to construct indices of productivity.

Productivity indices

We looked for indices which could measure the productivity of scientists for each of the years during their careers. Two kinds of productivity indices have been con-

*The Dutch universities are for more than 90% governement-funded; this system does not allow for substantial differences in rank between individual universities.

structed: one is based on the number of publications, the other on the number of citations in scientific literature. We will not deal here with the literature on the usefulness of these kinds of productivity measures (see for a review for example *Narin*[5].) The general conclusion is that these measures are adequate for the kind of statistical analysis performed in this study.

The *publication* productivity index of a researcher is calculated for each year the researcher has been active in research. The index for a certain year is based on the number of his publications published in that particular year. Some 'corrections' on this notion have been introduced: publications were given different weights according to the journal or series in which they appeared. Three classes. i.e. A, B and C, were introduced with weights 1.0, 1/2, 1/10 resp.*: class A contains international scientific journals covered by the *Science Citation Index (SCI).* Some high-ranking Dutch journals covering economics were also included in this category since it was found that economists generally do not publish in international journals. Class B contains other scientific journals and class C consists of congress papers, internal series, etc. This categorization is based on the fact that researchers give preference to publishing articles in well-known international scientific journals; these journals usually have a referee-system which guarantees a certain quality. Papers in other scientific journals will, generally speaking, be of a lower quality. The justification for a low weight for congress papers, internal papers etc. is given by *Meadows*[6] who states (page 118): "One general point does seem clear: significant research, however it first appears, usually surfaces eventually in the normal journal literature."

Another 'correction' regarding the weights attributed to publications concerned the degree of co-authorship: if a paper had n authors ordered alphabetically, each author was given $1/n$-th of the credit of that paper; if the authors were not ordered alphabetically, the first author, who usually is the main researcher, was given $(1/n$-1)th of the credit and the rest of the credit was equally divided among the other authors. Corrections of this kind are needed to prevent team workers (or people who added their names to each other's papers) from being favoured above individual researchers and to correct for the trend of increasing multi-authorship (see De *Beaver* and *Rosen*[7]).

In order to eliminate differences in publication habits between the disciplines, correction factors have been introduced to make the average productivity indices equal for each discipline.

The *citation* productivity index has been constructed as follows. For a researcher the index for year t (t running from the beginning of the research career up till 1982) is based on the number of times his publications, which were published in

*The final empirical results did not prove to be affected significantly by changing the weigts.

year t, were cited in year $t+1$ and $t+2$ (citation data from the *SCI*). Since economists (at least the Dutch) do not publish very often in journals covered by the *SCI* or *SSCI (Social Science Citation Index)*, citation productivity could not be determined for this group. For physicists and chemists the index could only be calculated for the years 1964 and onwards because the *SCI* does not cover the years before 1964.

The regression equation

As part of our study a multi-regression analysis was made. In this approach the dependent variable was the yearly productivity of a research scientist*; the main predictor variables were the mobility of a researcher and his age. Other variables used as predictor variables for productivity, included the time-period in which the research was performed and the generation to which the researcher belonged. These variables were selected because it was our assumption that these were related to productivity and either age or mobility. Moreover, age may influence productivity indirectly via so called intermediary variables such as the amount of time available for research, the type of research carried out (fundamental or applied), and the type of involvement (supervision or undertaking the actual bench work). These intermediary variables are also included in the regression equation as predictor variables. This approach enables us to isolate the direct effects of age and mobility on productivity from the indirect effects through these intermediary variables.

For a detailed description of the regression equation see *Appendix*.

Results

Methodological aspects

The (hypothetical) effect of a mobility event on productivity might be visualized as shown in Fig. 1.

In order to establish whether one or more of these mobility events have an influence on a researcher's productivity, the following method has been applied. The first step in the procedure is to estimate empirically whether a relation exists between the period of time lapsed since a mobility event (called 'stay') and the productivity. If so, the second step concerns with the causality in such a relation.

Whether 'stay' is related to productivity was analysed by means of regression analysis: the productivity of a researcher in year t (t running from the start of a

*The total number of observations for the dependent variable in our case is $7008 = \sum_i Z_i$, Z_i being the number of years individual i has been active in research; Z_i runs from 5 up till 45 years and has an average value in our sample of 15,6 years (7008/450).

research career until 1981, the year of our investigation), was taken as the dependent variable, 'stay' at time *t* as an independent variable (see *Appendix* for the regression equation used).

Significant regression coefficients for the variables measuring 'stay' may be taken to indicate that productivity is determined at least partly by 'stay', only if the two

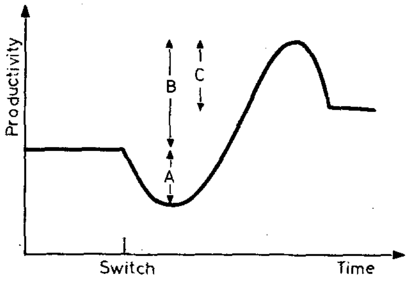

Fig. 1. A possible effect of a change of job or research field on productivity. A: fall in productivity shortly after the change because one needs to readjust oneself, B: rise in productivity due to the stimulus coming from the change, C: fall in productivity because stimulus peters out as one becomes adapted to new setting

following alternative possibilities can be shown to be incorrect or can be accounted for:

1. Both output level and "stay" are related to a third intermediairy variable;
2. Output level effects "stay".

In our case the former alternative is accounted for since the most likely candidates for such an intermediary variable are included as independent variables in our regression equation.* If they are included and 'stay' still appears to contribute significantly to the 'explanation' of productivity, it is reasonable to assume a direct relationship between 'stay' and productivity. Of course, this does not prove anything about the causality in the relationship. In order to elucidate this, additional analyses are needed.

This brings us to the second of the alternative explanations of a correlation between stay and productivity, that is that output affects stay.

This explanation, if true, means that the *intrinsic* productivity (level of productivity irrespective of influences of specific variables but typical of the type of person) differs between mobile and immobile scientists. This can be checked. In this case researchers who change frequently, should have a higher (or lower, depending on the sign of the correlation found) productivity not only after but also *before* a switch, disregarding other factors, than those who change less frequently. This can be verified by calculating for both groups of researchers the deviation of their actual productivity

*See *Appendix.*

before the switch from the estimated productivity (on the basis of the regression line). If there appears to be no significant difference in these deviations, the (second) alternative explanation of a correlation between 'stay' and productivity is not plausible.

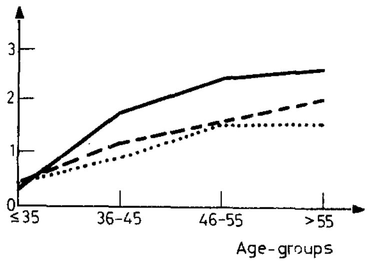

Fig. 2. The average number of job switches of researchers per age group and per discipline. Curves: —— physicists, - - - chemists, • • • economists

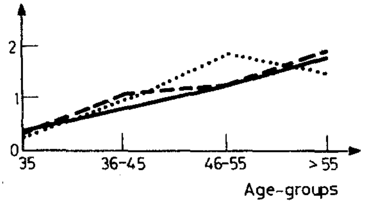

Fig. 3. The average number of changes in research fields of researchers per age group and per discipline. Curves: —— physicists, - - - chemists, • • • economists

In summary we conclude that on the basis of analyses as described before, it is feasible to determine empirically whether a change of job or field of research has an effect on productivity.

Our empirical results

On average the respondents had experienced 1.4 changes in jobs. For field mobility the average was 1.1. To a large extent the two types of mobility coincided. Job mobility is highest amongst physicists (Fig. 2); field mobility is found to approximately the same extent in each of the three disciplines in our sample (Fig. 3).

As expected, the mobility of a scientist is highly dependent on age: the opportunity to change must have been present.

Effects of mobility on publication-output

Regression analysis (see *Appendix* for the regression equation) shows that the independent variables regarding 'stay' (number of years since the last mobility

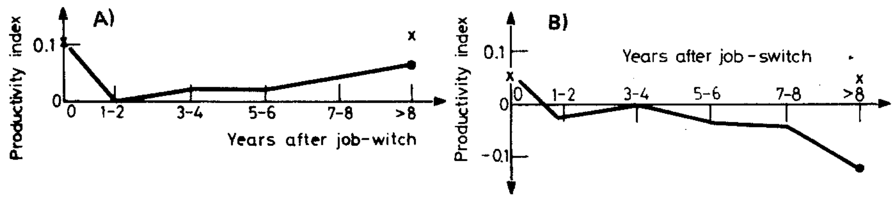

Fig. 4. The estimated effect of job mobility on publication productivity. Part A: The effect of a change of jobs at ages < 35. Part B: The effect of a change of jobs at ages ⩾ 35. [The results come from our regressions-analysis. Figure A resp. B give the estimated coefficients δ_{1j}'s resp. δ_{2j}'s of the regression-equation (see for the regression-equation the *Appendix*). Both sets of coefficients (δ_{1j}'s and δ_{2j}'s) contribute significantly to the explanation of productivity (F-test). The individual coefficients which are significantly different from zero (t-test; 5% level of significance) are indicated with large dots. For the explanation of the 'x'-points, see text. The zero baseline indicates the expected productivity of the researcher if no change of job or research field would have occured]

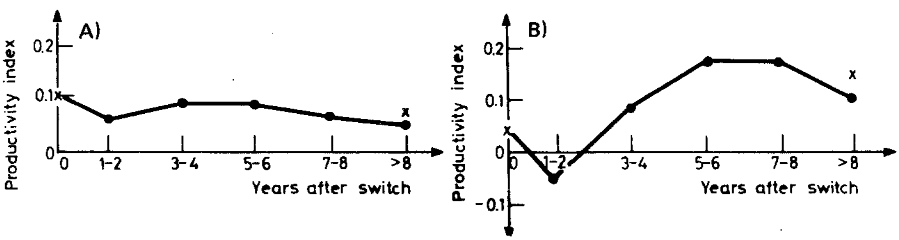

Fig. 5. The estimated effect of field mobility on publication productivity. Part A: The effect of a change of fields. Part B: The effect of a field switch in combination with a job switch [See legend Fig. 4. Figure 5A and 5B give the estimated coefficients M_{3j}'s and M_{4j}'s (see *Appendix*)]

event), for the different types of mobility* (except temporarily detachment), contribute significantly to the 'explanation' of publication productivity. However, as has been indicated earlier, additional analyses are required to draw conclusions as to the *influence* of mobility on productivity. Such analyses will now be discussed.

Figures 4 and 5 show the estimated coefficients for the (dummy-)variables for 'stay' after a job switch resp. field switch. The productivity index 0 represents the output level expected according to the regression curve for 'stay' = 0, i.e. for a situation in which mobility has not occurred.

*For the different types see var. $M_{ij}(t)$ in the equation in the *Appendix*.

For the interpretation of these graphs we first need to know to what extent the intrinsic productivity level (level of productivity irrespective of influences of specific variables but typical of that type of person) of mobile scientists differs from that of immobile scientists (see preceeding paragraph). The differences observed are plotted on both vertical axes. The point 'x' at the left vertical axis indicates the *difference* in intrinsic productivity between the highly mobile scientists (the ones who changed job c.q. field at least twice within 6 years) and the immobile scientists (the ones who never changed during their careers). The point 'x' at the right vertical axis shows the corresponding difference between the moderately mobile scientists (the ones who changed once but did not change again within 6 years) and the immobile ones.

From Figs 4 and 5 we conclude that mobile scientists do have an above average productivity (the intrinsic levels, 'x'-points, are above the zero line). Furthermore, only small differences were found in the intrinsic productivity between the moderately and the highly mobile scientists (the 'x'-points at the left and at the right vertical axis have about the same distance towards the zero-line).

Job switches. Given intrinsic productivity differences between the various groups, which conclusions can be drawn from the graphs as presented in Figs 4 and 5? From Fig. 4A we learn that the productivity drops after a job switch under the age of 35 (productivity in the first two years after the switch is below the intrinsic level of the mobile scientists); shortly after the switch, productivity appears to recover slowly but it does not end up above intrinsic level. There is no evidence, therefore, that a job switch stimulates publication productivity. A job switch at a later age (above 35) seems to have negative results: productivity 8 or more years after the switch is significantly below the intrinsic level (see Fig. 4B).

Field switches. From Figs 5A and 5B it appears that a switch of research field has an impact on publication productivity only if it is accompanied by a change in jobs. Apparently a field switch without changing jobs is coped with rather smoothly (in Fig. 5A the coefficients and the 'x'-points are more or less on a horizontal line). Figure 5B shows that if both field and job are changed at the same time, productivity initially drops after the switch, but at a later stage rises rather sharply and attains a level superior to that without such a change (the graph reaches levels beyond the 'x'-points). There is no indication that the type of switch mentioned here has a lasting positive effect on productivity: the coefficients for stay periods beyond 5 years hardly differ from the intrinsic level of the (moderately) mobile scientists. Therefore the conclusion may be that, generally speaking, mobile scientists are characterized by a relatively high publication productivity; there is no evidence that mobility itself enhances publication productivity.

Differences between highly productive and less productive researchers. Results presented so far have been obtained by analysing productivity data of all the scientists in the sample. To refine our analyses separate calculations were made for highly productive scientists and for the remainder of the sample.

The researchers are divided in highly productive and less productive on the basis of their productivity in the first five years of their research career ('initial productivity'). The justification for this operationalization is given, among others, by studies

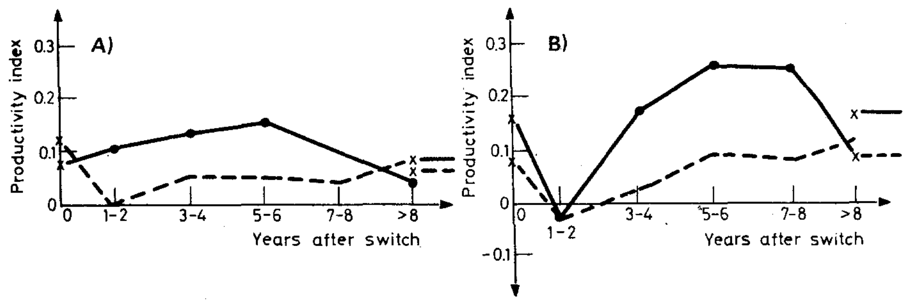

Fig. 6. The estimated effect of mobility on publication productivity for productive and less productive researchers. Part A: The effect of a change of research field without a job switch. Part B: The effect of a field switch in combination with a job switch. Curves: —— the group of most productive scientists, - - - the group of less productive scientists [See legend Fig. 4. For the definition of productive and less productive researchers, see text]

of *Meltzer*[8] and *Cole*[9] which show that the most competent researchers generally publish relatively frequently from the onset of their careers. It was found that for each subgroup separately – the group of highly productive scientists and the rest – variables associated with *job* mobility did not contribute significantly to output. For *field* mobility, or for field mobility in combination with job mobility, the situation was found to be different. Figures 6A and 6B show that the highly productive scientists tended to benefit from a change. For this category the productivity a few years after the switch was somewhat higher than the intrinsic level. No net long term effect was observed, however, as after 8 years the output had declined to attain the intrinsic level once again. Less productive scientists did not show a temporarily positive response to the stimulus of field mobility.

Differences between disciplines. For the different disciplines parameters associated with *job mobility* per se (not accompanied by a change in research field) did not contribute significantly to explaining productivity, except in the case of physicists who changed jobs at ages above 35. This group experienced a reduction of productivity as a consequence of shifting to a new position (figure not shown). Except for physicists, the variables for *field mobility* contributed significantly to output level.

As shown in Fig. 7, a change of research field either without (A) or with (B) a concomittant job mobility event tended to have a positive effect on the productivity of chemists. Economists on the contrary did not benefit, but experienced a significant set-back.

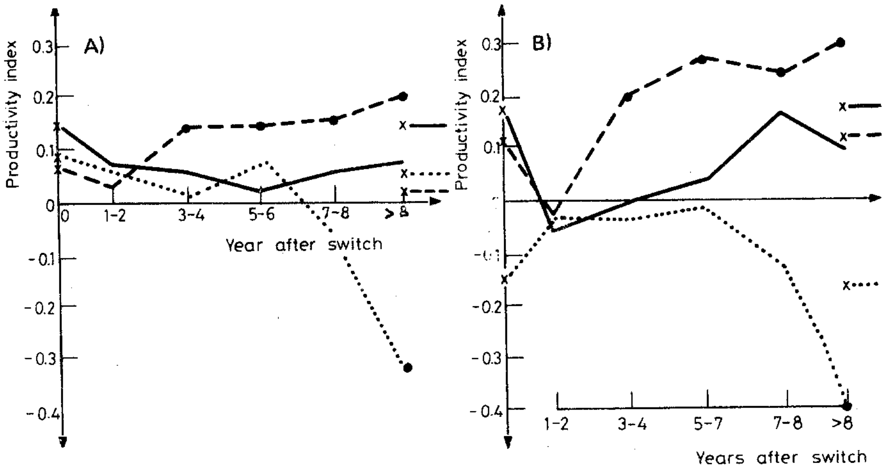

Fig. 7. The estimated effect of mobility on publication productivity per discipline. Part A: The effect of a change of research field without a job switch. Part B: The effect of a field switch in combination with a job switch. Curves: —— physicists, - - - chemists, · · · economists
[See legend Fig. 4]

Moreover, it was found that, contrary to physicists and chemists, *economists*, who have changed jobs are characterized by a relatively low productivity compared to the economists who remained immobile ('x'-points below zero-line). This corresponds to the findings of *Crowley* and *Chubin*[1] pertaining to sociologists which have been refered to in the introduction.

Effects of mobility on the impact of publications

The results presented so far pertain to the productivity of scientists expressed in the number of publications. Mobility, it appeared, does not enhance this kind of productivity. However, whilst not stimulating a scientist to publish more, mobility might still be assumed to scientist's work. In order to establish the extent to which this is the case, additional regression analyses were performed along the lines as described before with a productivity index now based on the number of citations received.

In these analyses only physicists and chemists were included. Reliable citation data for economists were not available. Figures 8A and 8B show that job mobility, as was the case for written output, does not affect the citation levels. Figure 9A suggests,

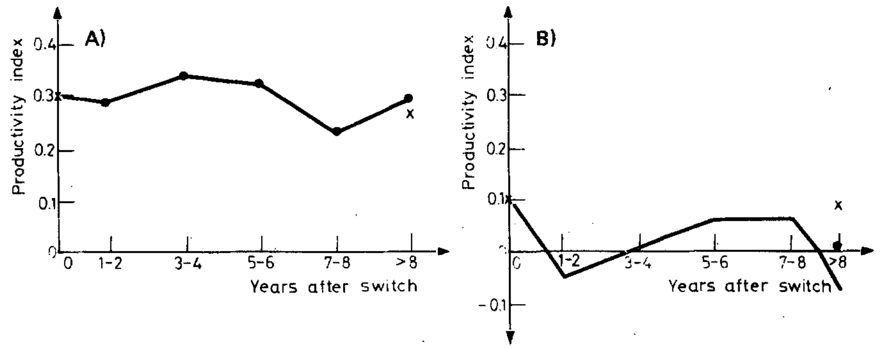

Fig. 8. The estimated effect of job mobility on citation productivity. Part A: The effect of a change of jobs at ages < 35. Part B: The effect of a change of jobs at ages ⩾ 35. [See legend Fig. 4. Estimation based on data regarding physicists and chemists; for economists no citation data were available]

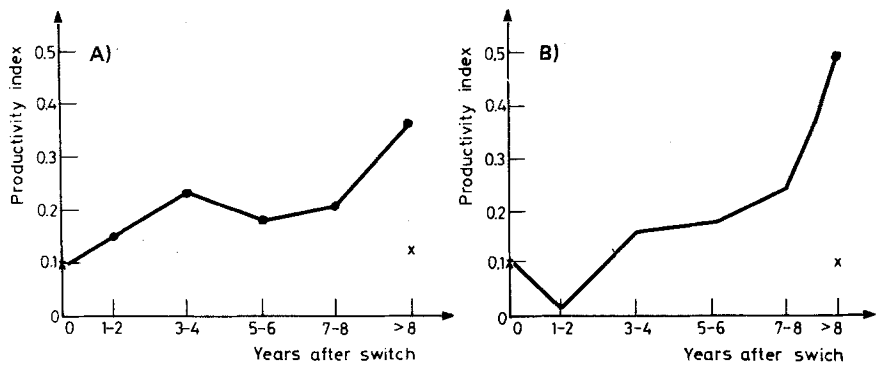

Fig. 9. The estimated effect of field mobility on citation productivity. Part A: The effect of a change of research field without a job switch. Part B: The effect of a field switch in combination with a job switch
[See legend Fig. 4. Estimation based on data regarding physicists and chemists; for economists no citation data were available]

however, that a change of research field has a positive long-term effect on citation frequency. Publications written some years after the change have a significantly higher impact than publications produced prior to the change. This result is also found for the effect of field and job mobility combined. Since the citation frequency attained after a change is significantly higher than the intrinsic citation level, it can be concluded that field mobility has a positive effect on the impact of scientific work.

Summary and discussion

The literature regarding the effect of mobility on productivity is very limited. Our study indicates that, though job mobility is mostly observed among scientists with a high productivity, job mobility without changing research field cannot be considered a means to stimulate productivity. On the contrary, at ages over 35 an adverse effect is usually observed.

It is primarily a change of research field that appears to stimulate a scientist's productivity. Though she/he will not publish more articles, the impact of her/his scientific work is significantly enhanced.

The results of our study throw grave doubt upon the sense of a general policy directed towards stimulation of job mobility insofar as aimed at a stimulation of research productivity (there may of course be other reasons for a stimulation of job mobility). A change of jobs generally does not have a positive effect on research output. Field mobility rather than job mobility generates the effect looked for. For a change of that kind high barriers may present themselves. A scientist contemplating such a move will have to start anew, leaving the setting in which his contribution was recognized. It can therefore easily be conceived that instead of general means, good research management will be absolutely necessary to convince the scientist in question of the advisability of such a move.

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Appendix

The regression equation used in our analyses, looks af follows:

$$Y(t) = \sum_{i=1}^{15} \alpha_i L_i(t) + \sum_{i=1}^{14} \beta_i P_i(t) + \sum_{i=1}^{14} \psi_i G_i + \sum_{i=1}^{5} \sum_{j=1}^{5} \delta_{ij} M_{ij}(t) +$$

$$+ \sum_{i=1}^{2} \rho_i a_i(t) + \sum_{i=1}^{2} \tau_i b_i(t) + \sum_{i=1}^{2} \kappa_i c^i(t) + \sum_{i=1}^{4} \mu_i d_i + u(t) + \text{constant term}$$

with

$Y(t)$: productivity of the researcher in period t (see main text for definition of productivity),

$L_i(t)$: dummy-variables to indicate the age of the researcher in period t;
$L_1(t)$=1 if researcher belongs to age group 21–23 years at t else 0,
$L_2(t)$=1 if researcher belongs to age group 24–26 years at t else 0.
etc.

$P_i(t)$: dummy-variables to indicate the period of time;
$P_1(t)$=1 if year t falls in the period 1946/48 else 0,
$P_2(t)$=1 if year t falls in the period 1949/51 else 0.
etc.

G_i: dummy-variables to indicate the generation to which the researcher belongs.
G_1=1 if the researcher is born in the period 1911/13 else 0,
G_2=1 if the researcher is born in the period 1914/16 else 0.
etc.

$M_{ij}(t)$: dummy-variables to indicate for the researcher the time between year t and the latest mobility-event of type i (measured in years, called a 'stay' of j years at time t).
i=1: a job switch under age 35,
i=2: a job switch beyond age 34,
i=3: a field switch without a job switch,
i=4: a field switch in combination with a job switch,
i=5: a temporary detachment.
$M_{ij}(t)$= (for j=1, 2. . .4)
- 1 if time difference between year t and the latest mobilityevent of type i ('stay') is equal to $2j-1$ or $2j$ years,
- 0 if not

$M_{i5}(t)$=
- 1 if time difference between year t and the latest mobilityevent of type i ('stay') is larger than 8 years,
- 0 if not

$a_i(t)$: dummy-variables to indicate for period t the type of research (fundamental, applied or a mix of both) the researcher is doing.
$a_1(t)=1$ if the researcher is doing only fundamental research in period t else 0,
$a_2(t)=1$ if the researcher is doing both fundamental and applied research else 0.

$b_i(t)$: dummy-variables to indicate for period t the type of involvement (supervising, actual benchwork or a mix of both) of the researcher.
$b_1(t)=1$ if the researcher is only supervising in period t else 0,
$b_2(t)=1$ if the researcher is supervising part of his time in period t else 0.

$c(t)$: percentage of time in period t the researcher has available for research.

$c^2(t)$: $c(t)$ squared.

d_i: dummy-variables to indicate the type of department the researcher is working at; the following types have been discerned: academical physics, technical physics, academical chemistry, technical chemistry and economics.

$u(t)$: error term.
α_i, β_i, ψ_i, δ_{ij}, ρ_i, τ_i, κ_i, μ_i are coefficients.

Total number of researchers in the sample: 450.
Total number of observations: 7008.