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Mobility of researchers – policy, models and data

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1. Introduction[1]

Mobility of researchers is increasingly becoming a prioritised focus of science, technology and innovation policies. In a European context there is a longstanding objective in enhancing transnational mobility within the research community, increased mobility being seen a vital instrument to achieve an improved integration of research systems. More recently however, mobility of qualified scientists and engineers from universities and other research institutions into the business world has increasingly been seen as having to major effect that are beneficial for the interaction between the business and research systems. Increased inter-sectorial mobility is seen as an important instrument for transferring scientific expertise *to* companies and to build up their wider research capabilities. This will allow, it is argued, companies to react more effectively to rapidly changing technology, and to more efficient outsourcing of research activity. Enhanced mobility will - especially *from* business to the research institutes - lead to increased awareness of and attention to business needs and opportunities. Jointly these two outcomes of increased inter-sectorial mobility will lead to improved interaction between industry and academia, leading to more efficient and effective social utilisation and adaptation of science.

Policy objectives and initiatives considering inter-sectorial mobility of researchers need to address trade-offs between the present and future needs of business and the requirements for well-functioning R&D institutes at an inter-sectorial and inter-institutional level, considering the system-wide direct and indirect impacts of suggested initiatives. Yet we generally encounter a rather naïve one-dimensional approach based on the perception that present mobility rates are too low, and that with more mobility, the better and more efficient economic and social effects of the activities of the R&D system will be.

At European level *Training and mobility of researchers* is a longstanding and rapidly expanding priority within the Commission's Framework programmes. The horizontal action line within the fifth Framework programme was allocated a budget of more than € 850 million for the period 1998-2002. The Commission communication on the *European Research Area*[2] explicitly targeted inter-sectoral mobility as a policy priority;

> *More use should be made …[of] mobility as an instrument of information and technology transfer. The mobility of researchers between the academic world and the business world, in the different forms that this might take, should also de readily encouraged and developed.*

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[1] This paper partly builds on previous work by Johan Hauknes, "Modelling the mobility of researchers", STEP-report, 9-94, but contains an more thorough verbal discussion of the problems. More and newer empirical material based on register data that has become available since 1994, and a discussion of the mobility enchanching programme of the Research Council of Norway. It is also less mathematically demanding. Those interested in a more rigorous and detailed mathematical formulation should consult the STEP-report

[2] European Commission, *Towards a European research area*, COM(2000)6, Brussels, 18 January 2000

The conclusions of the Lisbon Council, following up this Communication, led to the establishment of a high-level expert group on improving the mobility of researchers. The group delivered its final report to the Commission in April 2001[3].

This emphasis is also reflected in a number of national programmes. Various instruments are in place to promote intersectorial mobility and training in industry in all countries within the EEA, whether to promote mobility of researchers from academia into industry, or to facilitate opportunities for business employees to take up positions within the research system. Scientists and engineers can be seconded to industry at subsidized cost, with additional support to the science institution. In several countries, programmes have been organised to stimulate temporary mobility from academia to industry.

A few years ago a large scale support programme to promote increased mobility of researchers was initiated by the Research Council of Norway. The original proposal was for support of the order of NOK 150 million, but due to budgetary constraints it was ultimately scaled down to 36 million NOK (approx. € 4,5 million) over five years. The programme objective was to enhance R&D capabilities in SMEs and in industries with low R&D intensity, to stimulate permanent and temporary employment of experienced R&D personnel in industry and to fund temporary employment of industry employees in R&D institutes and universities. Several instruments were organised to achieve this, such as

- up to 50% subsidies of first year salaries of R&D personnel taking up a position with a company,
- funding 50% of costs in three years related to temporary employment/researcher-for-hire,
- 100% coverage of costs during two years of employment of recent Ph.D.s in companies, and

grants of up to 50% of total salary costs during three years to fund company employees with temporary employment or post-grad education in R&D institutions.

In all the instances outlined above, and even though inter-sectorial mobility rates of researchers are generally higher than for the remaining work force, present levels of researcher mobility is seen as a barrier to effective and beneficial social utilisation of the science and technology base. There are perceived social benefits to be reaped from increasing these mobility rates, generated by industry's improved capabilities to exploit scientific and technological opportunities and by providing stimulus for generating a scientific and technological research agenda adapted to business needs and opportunities.

This priority of inter-sectorial mobility of researchers should thus primarily be understood as deliberate attempts to strengthen industrial and wider social *effects* of scientific and technological research and of the related knowledge base. Increased mobility is seen as an important way of dismantling the barriers companies face in accessing and using this knowledge – or science – base, by providing access to

[3] European Commission, *High-level Expert Group on Improving Mobility of Researchers – Final Report*, DG Research, 4 April 2001

formalised, or codified, dimensions of this base – integrated with proficiency in the tacit dimensions and capabilities required to access and develop this base.

Mobility has, however, a dual aspect. If it enhances capabilities in recipient institutions, then presumably it may also have negative impacts on the supplier institution. This may particularly be the case if research-based knowledge is produced not by individuals but by teams where learning between persons, generations and scientific fields is very important. These diverse learning processes in turn often lead to collectively based generation of knowledge and competences. In such a case mobility might disrupt team activities. Consequently there is a more or less complex trade-off between positive benefits accruing to a recipient institution, and negative impacts on the delivering institution.

In none of the policy initiatives discussed above are these associated negative effects of increased mobility considered. Rather, increased mobility rates are seen as undisputedly beneficial. We claim that this is a reflection of a too simplistic interpretation of the processes that underlie the organisation and performance of scientific and technological activities in R&D institutions. Generally the organisation of these institutions must be seen as a complementary interaction of mutually interdependent personnel with many levels of expertise, experience and capabilities.

The main purpose of this paper to discuss some aspects of this trade-off when considering personnel flows from R&D institutions to companies. A core question here is how a more appropriate assessment of the disrupting and beneficial effects of inter-sectorial mobility may be done. The paper will develop some simple models that may form the basis for a more appropriate trade-off analysis. The models are confronted with empirical evidence on personnel flows from Norway, concentrating on the polytechnic, industry-oriented contract R&D institutes, but the arguments in this paper are general and applies to all R&D institutions. It is, however, restricted to the impact on R&D personnel and does not consider the supply of graduates and Ph.D.s from universities as part of their educational objective.

The empirical focus on mobility of researchers from the Norwegian institute sector is based in this sector of private non-profit contract research institutes being the major institutional sector in the Norwegian research system intended to serve industry needs. Rather than universities, these institutes are the main entrance points of industry to the research system. This designed division of labour between universities the polytechnic institutes implies that 'technological' or 'cognitive' proximity of the science and technology base to industry is primarily located within these institutes.

2. The importance of being mobile

2.1. The mobile rationale

Basically, mobility of researchers between a research-performing (RP) sector and a research-using (RU) sector is a *quantitative* phenomenon, described by the absolute or relative number of researchers moving between the two sectors. But what make this quantitative phenomenon worthy of policy focus are its *qualitative* aspects. Mobility becomes an important social and policy issue only when we go beyond the quantitative dimensions of mobility rates and volumes, and beyond simplistic notions of technology and technology diffusion.

It is when technology and technological knowledge are not seen simply as a set of blueprints, or shelf-ware, that the need to study processes by which persons, groups and organisations acquire and generate technological competences and knowledge becomes imminent. The extensive literature on topics related to the structure and dynamics of technological knowledges clearly demonstrates the complex nature of these knowledges and the basis it provides for industrial production (see f.i. Nonaka (1992), Faulkner and Senker (1994), Lundvall (1998), Hales (2001)). Even by simply distinguishing on the one hand between generic and specific knowledge and between tacit and codified knowledge on the other, open up for complex structures and dynamics of knowledge generation and utilisation.

Acquiring and accessing state of the art technology then clearly become a more ardent task than transferring the requisite piece of knowledge from producer to user. This immediately suggests one significant way of transferring useable knowledge into industries and companies, these being perceived as the main locus for the generation of the social and economic benefits of the codified scientific and technological knowledge knowledges – of the S&T base. By hiring personnel having already acquired the necessary tacit insights and expertise needed to understand and transform these knowledges – scientists and engineers with R&D experience – into production competences, a bundle of already integrated codified and tacit competences is transferred. These arguments imply not only that increased mobility *from* R&D institutions *to* companies has a direct enhancing effect on the companies' ability to use scientific knowledge. They may even be taken to suggest that personnel flows should be the main vehicle of transferring the S&T knowledge base from the R&D system to industry.

Ultimately this would suggest that the relevant parts and institutions of the R&D system should be primarily seen as personnel training facilities. I doubt, however, that any policy maker or S&T analyst would seriously suggest replacing the research objectives of these institutions with education and training objectives. The implicit premise being that research and knowledge generating activities in these institutions require a balanced division of labour between experienced and inexperienced – and between trainer and trainee – where a to strong prioritisation of training and mobility would ultimately prove counter-productive. There is a balance to be struck between generation and diffusion.

2.2.Understanding mobility - models

Hence, the various policy initiatives mentioned above suggest an implicit assessment that wherever the requisite social trade-off between developing the S&T base and transferring its contents to industry lies. There is implicit in these arguments a notion of a socially optimal region – or points – of mobility rates. There are still benefits to be reaped by increasing present mobility rates – the national and European systems are still below this trade-off point. The problem here is that the issue of the dynamics underlying this social optimum and its location is never considered. Furthermore there is a lack of any instrument or model of discussing these issues. We have ultimately no guides to where the suggested social optimum lies. The purpose of this paper is to open a way of approaching these issues, by developing a series of alternative schematic models of labour mobility that allow us to confront them. The purpose of these models is twofold; firstly to outline a basic framework for modelling mobility issues and secondly to provide alternative 'mental models' for thinking about researcher mobility and related issues. These alternative models should be more reasonable than the 'common sense' ones evidently used as a basis for several policy initiatives, through retaining – at least a major part of – its simplicity.

The sole focus of positive impact of labour mobility in recipient institutions, excluding considerations of the negative impacts on supplier institutions, implies an implicit model of personnel mobility. R&D personnel in the supplier organisation is substitutable – essentially there are no divisions of labour within the R&D organisation. There are only possible scale impacts to consider. There are no structural impacts of mobility - and hence no qualitative impact – on the supplier organisation. A further implication of this is that the group of mobilized researchers is treated as homogenous – all researchers are identical. These aspects are captured in the first model outlined below – the tube. Hence we are lead to the conclusion that recent policy initiatives are based on a mental model that at least shares basic characteristics with this. The refined models outlined attempts in simple ways to approach these basic shortcomings of the tube model.

2.3.Further issues

Mobility flows between the R&D system and industry are going both ways. As well as researchers moving R&D institutions to industry there are scientists and engineers – with or without R&D experience – moving from companies to R&D institutions. This counter-flow has an indirect – although not necessarily less important – effect on the development of scientific knowledge. Personnel in a S&T-using environment – as in industry – tend to be more focussed on satisfying user needs, and searching for opportunities for further operationalisation of available and potential knowledge. The presence of such personnel in R&D performing organisations within the science system will presumably impact on the scientific agenda and content in two ways. Firstly, and in the short run, it will strengthen the competences in the R&D system to relate to and mediate its researches to industry users. Secondly, in a longer run it may expand the set of criteria used for choosing research focus and hence shape the focus of research efforts in these institutions, aligning it more closely to business needs and opportunities. The interlaced structure of the relevant S&T bases and the complex set of competences needed for its development emphasise, however, that design of technology and wider R&D objectives, even when ultimately addressing economic and industrial development (see f.i. Hauknes (1998)), are not simply a question of aligning R&D strategies and policies with business requirements. These issues go beyond this paper.

As seen above, several of the policy initiatives involve stimulating both permanent and temporary movements of personnel between the two grand sectors. In reality, researcher mobility involves all shades of grey, from short project-related stays by R&D personnel in client organisations to permanent shifts in employment from one sector to the other. It may involve hiring, formal employment or project-based purchases of R&D time or expertise, in a specific or a general context. Presumably the overall impact varies with the different forms mobility may take. This paper lumps various mobility patterns into one single category. The mobility captured by the models below should be understood as capturing modes of mobility where

- the researcher is fully integrated into the recipient organisation, i.e she or he is employed or hired by this organisation for work under the control of the recipient,
- if temporary, the transfer is of sufficient length to have impacts on the structure or operations of the supplier organisation beyond the termination of the researcher employment.

2.4.The Norwegian contract R&D institute sector

Broadly speaking publicly funded and organised research in Norway is based on an institutional system consisting of two parts - a system of universities and other higher education institutions (HEIs) - and a system of (semi-) public[4] contract R&D institutes, commonly denoted as the institute sector. The HEIs are characterised by their dual objective of education and training on the one hand and research on the other. The R&D institutes have substantial public funding, and are generally seen as national resources of technological knowledge and research within their own area of expertise. As such they are seen as a major element in the institutionalisation of the national S&T knowledge base. The development and supply of a basic resource of knowledge and expertise in key technology areas is accepted as an area with considerable public responsibility. Thus these institutes receive substantial core grants and other funds for the development of these resources. Though generally organised as private non-profit organisations, with research activities funded mostly either through outsourced R&D from industry or from publicly funded projects in close collaboration with industrial companies they are from the research and innovation policy perspective still seen primarily as vital parts of the public 'knowledge infrastructure' (Smith 1998, Hales 2001).

[4] Publicity is defined in terms of access, not of ownership. The RI system thus consists of research establishments that may be accessed by groups or categories of 'research users'. This includes institutions such as governmental laboratories, HEI-based research and extension centres, autonomous research institutions and institutions organised by industry associations.

Usually there will be close correlation between publicity in these terms and the degree of public funding of the research activities.

The position of these R&D institutes in national science and innovation policies implies quite specific policies and policy objectives designed to influence the their end their employees activities. Mobility stimulating schemes might be a part of such a policy. Related types of RTOs (Research and Technology Organisations), like the Dutch TNO and the Finnish VTTsystems, exist in several European countries, though the specific organisation, their functional role and relative size differ considerably between countries[5]. In general these organisations typically have a substantial basic funding from public authorities, in part to fund generic competence and knowledge development.

As a basic rule these institutions are non-profit, and often explicitly so. The institutions legitimise themselves in terms of performing *research*, based on staff members' identification as *researchers*. Their core objective is to develop and provide technological knowledge catering for long term industry needs, depending on both internal scientific and external relevance criteria. The perception of a conflict between scientific and industrial research objectives and a split appraisal of overall research quality/relevance, high 'relevance' and high 'quality' somehow being perceived as contrary objectives, contributes to explaining the interest in mobility stimulating schemes (MSS) from policy makers. The stimulation of mobility rates is proposed as a way to 'narrow the gap' between the two systems.

The attention given to mobility issues by policy makers is in itself a reason to map mobility rates, to analyse mobility as an element in knowledge and technology diffusion and to analyse the effects of mobility at the receiving and delivering ends of mobility channels. The present paper is a part of a larger study partly based on such reasoning. But in addition our work in this field is based on an interest in mapping and understanding the dynamics of technology diffusion.

As technology diffusion is heavily integrated with the flow of tacit knowledge and skills, actual contacts between people – including researchers – ought to be a decisive factor in the outcome of diffusion processes. These flows and contacts take many forms, of which actual mobility is but one. To the best of our knowledge there is no literature which systematically assesses the different forms of mobility in relation to technology diffusion. [6] On the other hand there are many that argue that mobility is important.

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[5] The Norwegian institute sector was formally de-connected (fristilt) from the public sector in the late eighties. This was a part of the general trend in European countries in their policies towards RTOs that was later denoted the 'KIBSification' process, see Hales (2001) and other background material to the European RISE-project. On the structure of European RTO systems and their roles, see also Senker (2000).

[6] Even a classic reference in the diffusion literature such as E. M. Rogers **Diffusion of Innovations**, The Free Press, New York 1983, 4th edition 1995, does not mention of transfer of individuals as a way of disseminating knowledge. In fact the definition of diffusion given by Rogers, "the process by which an innovation is communicated through certain channels over time" (Rogers, p. 10) excludes physical flow of individuals. Neither of the two social roles *opinion leaders* and *change agents* that he discusses, cf. chap. 8 and 9, includes the role of a transformation between the two, from a change agent role to an opinion leader.

2.5. An example

One typical example is John Hendry, who in his book on the emergence of the computer industry in UK, "Innovating for failure – Government policy and the early British Computer Industry" writes:

> *The second characteristic[7] of the American environment was its pervasive entrepreneurial spirit and, closely associated with this, the mobility of engineers between firms, universities and defence establishments. …. If we look at the transfers of individuals and know-how between British computer projects and firms we find little beyond the early bilateral arrangements between firms and research centres (Lyons and Cambridge, Ferranti and Manchester, English Electric and the NPL), and the transfers resulting from the defensive mergers and acquisitions of the 1960s. …. If we look to America, however, the movements are so many and so complex as to defy any simple form of description or illustration.*

Hendry then gives a full page of examples and continues:

> *This sketch of movements and relationships in the early American computer industry is far less complete than that given for the British industry, but it is already far more complex. It also shows clearly the importance to the development of the American industry of the migration of groups of engineers leaving one organisation to set up a division in another or to set up on their own. If we look just at the independent new ventures, we find over a dozen in the period covered by this book, and a fuller survey would show several times as many.[8]*

Note that Hendry speaks of "groups" of engineers. This is in stark contrast to the focus of all the mobility stimulating schemes outlined above, which all operate at the level of individual researchers. In fact there seems to be a complete lack of any discussion of group mobility along the lines of Hendry's argument. Hendry's point is clearly more related to generation of spin-off companies, NTBSs and related, spun off from academic research. Clearly there is an important question here, of the relative importance between group and individual mobility.

The unquestioned focus of individual mobility of these policy schemes may in part be based on a traditional, folklore view of university research mainly being organised around the gifted individual professor. One might question if this is an appropriate implicit model when it comes to technological research and innovation, where innovations are often the result of new combinations – and further development – of known technologies.

Whatever the explanation for this bias towards individual mobility, a core question for the future formulation of policies and analysis in this area is where the R&D-based scientific and technological competences of R&D institutions reside. Are they collective or organisational or individual competences? This relates directly to a question concerning the rationale of such mobility stimulating schemes. Is it an attempt to transfer competences and capabilities *in lieu* of experienced individual researchers, or is the primary objective to establish communication channels back to mobilised researchers' former R&D organisation and networks? In the latter case, where implicitly the aim is to enhance absorption capacity in the recipient

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[7] The first – and most important according to John Hendry – being the sheer size and the relatively greater financial contribution of government over the defence budget to the computer industry in America that was clearly greater, by order of magnitude.

[8] Hendry, 1989, p. 163 - 165

organisation, it may make sense to focus exclusively on individual mobility. In the former case, with an implicit objective of enhancing the in-house R&D capabilities of the recipient firm, it does not make sense if it is acknowledged that S&T capabilities of R&D institutions are generally organisational.

The point we want to maker here is that the inherent skill bases of business enterprises are continually changing and closely dependent on and determined by the tacit and formal knowledge of the workers. This suggests that experienced individuals – and this may be even truer of whole research teams - introduced to this environment may have significant effects on the future development of this base, and through this on the future development of the enterprise.

However at the same time as the receiving firm is supplied with an experienced researcher, the research institution loses one. This quality-reducing effect of researcher mobility is often forgotten in deliberations on and policy formulation of MSS.

3. The rationale for using models

The interest in mapping and stimulating mobility patterns is largely based on two assumptions. Firstly, there must be potential benefits to be gained from better use or allocation of these productive resources, i.e., that present use of scientific knowledge in business enterprises is sub-optimal in some way. This implies the need of fostering or forcing a re-allocation of S&T resources. Given the emphasis of non-codified forms of and experiential knowledges, the target of mobility of experienced researchers is rather immediate. There is an implicit corollary here, however. The expected benefit gains must at least surpass the total costs, including opportunity costs, of the policy. Irrespective of the complexity and scale of the problem this raises, it is a major weakness of such efforts that no attempts have been made to approach them.

This is independent of whether the problem is a lack of awareness of the potential use of S&T resources in firms or the present levels reflect private rational expectations, f.i. due to high initial or transaction costs, or appropriability problems. In the first case there is a need to have a qualitative understanding of the reasons for and nature of the lacking awareness, while the latter implies needs for a more considerate understanding of the associated gap between private and social benefits from inter-sectorial mobility.

Existing policy documents suggests that the perceived problem is one of lacking awareness. In the Norwegian context this is reflected in the priority of the Mobility programme given to SMEs and industries where present levels of R&D are low. The second assumption concerns lacking awareness in firms directly. R&D institutions are not perceived as ‘relevant’ enough, i.e., there is an apprehension gap between the two grand sectors that is largely due to the S&T institutions’ retraction from industry needs and characteristics. Being too science-oriented, they are not sufficiently oriented towards the R&D and wider technological needs of their actual or potential clients.

These two assumptions seem to underpin the demand for mobility stimulation schemes, but they have to our knowledge not been subject to empirical or logical analysis, their factual basis is left more or less unverified. However, we are not arguing that they are unreasonable. On the contrary, we tend to believe that mobility of researchers has an overall positive effect on the economy, in spite of the lack of direct empirical or analytical evidence. As long as potential employers signal a positive price for the competence of experienced researchers, this shows an expectation of a positive value by the firm. On the other hand, enhancing mobility rates may have negative effects on the research institutes. Everyone would probably agree that an annual mobility rate of 50% would quickly destroy a research institute’s ability to generate useful knowledge and/or innovations. On the other hand, a very low (2-3%) mobility rate may lead to too little exposure to new ideas, too little innovative research and to much work marked by routine. So the question is really, where is the reasonable and beneficial middle ground?

If we assume that the demand for researchers by companies is an increasing function of research experience, and that researchers themselves seek new opportunities to implement the results of their research, than age distribution in research institutes will be skewed. There will be many young (broadly aged 25 – 40 years) and relatively few older (broadly aged 45-65 years) researchers.

Striking a balance between the two opposing forces is hard, but the desire to change existing mobility patterns has to consider this balance. If one accepts that the present mobility pattern is an outcome of the dynamic properties of the system, than it is also evident that this pattern reflects a balance between these opposing forces. Unless one is certain that one's own knowledge of potentialities exceeds that of the primary actors – the researchers, their institutions and the business firms – then there is clearly a need for caution. This is especially important if the actual patterns are stable in time and space (which they generally seem to be, see below).

In the last instance, however, one would have to base policy formulation on some kind of conceptual view of how these two antithetical processes (benefits from knowledge transfer and costs of 'team' loss) interact with each other. This is where formal model building might be useful. Models have their prime rationale in terms of highlighting, visualising and rigorously exploring the implications of intuitions. But equally, models are an aid in structuring the understanding, and informal analysis, of a problem. The construction and mental assimilation of appropriate models is a foundation itself for the intuitions formed, whether by the analyst, the policy maker or the casual observer.

The Research Council of Norway established, in 1993, a 15% annual target for mobility rates from technologically oriented research institutes. The target has later been revised downwards to 10% (RCN, undated). The reasons for this revision are unknown, but we note that the cited memo, in presenting a self-evaluation of the Mobility programme for 1994-1998, makes the point of disruptive impacts on the R&D institutions of too high mobility rates. The target is taken to have validity across a wide range of technologies, institutions and business sectors. One would expect that such a target would be established through consideration of the underlying dynamics and of optimality conditions. This does not seem to have been the case.

4. Three simple models

We will use three simple models to illustrate the general points made above. Two of the models are clearly unrealistic, but may be useful as stepping stones towards a more realistic description.

4.1. The tube model

The research institution is composed of *M* age classes of equal size *n*. Every researcher stays in the institution for *M* years, and at the end of the period the whole age class quits[9] and finds occupation in other sectors of the economy. An age class of 'experience', or age, 0 replaces the outgoing age class. The aggregate mobility rate, n/N, where N is the total number of research staff, $N = nM$, simply becomes the inverse of the number of cohorts M, or $1/M$. Mobility rates depends solely on the number *M* of equal-sized cohorts of researchers in the tube. The tube is thus seen as analogous to a school; with exit only in the graduation year *M*.

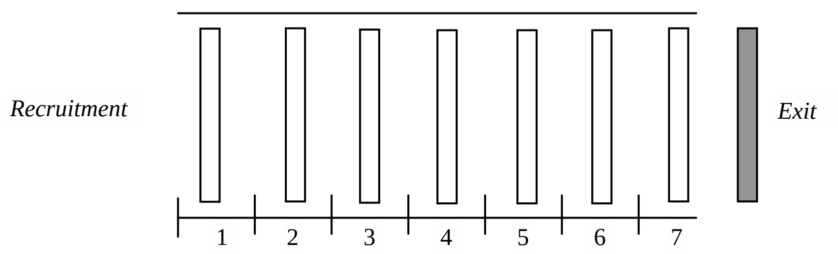

Figure 1. The tube model for M = 7. Mobility rate 1/7 = 14%

The general model is fully described with the cohort specific mobility rates,

	Cohort 1	*Cohort 2*	……….	*Cohort* M-*1*	*Cohort* M
Mobility rate	0%	0%	……….	0%	100%

The simplicity of the tube model and of the structure of intuition it creates is intriguing. Furthermore, as argued above, this model seems to be behind the main rationale of mobility stimulating schemes. It should, however, be immediately clear that this model is a fundamental misrepresentation both of main empirical patterns of labour mobility and of the system impact of mobility. All mobilised researchers are seen as equivalent, being all members of the same homogenous cohort.

One could also have called this model the "primary school" model where everybody enters in the lowest class and graduates at the end of the " tube". The mobility rate

[9] The process of leaving the institute of course is a process in continuos time, but we look at it as a discrete process where all 'movers' leave the 1st of January every year. Often we have only yearly data, so we can only tell if there has been a job shift between to calendar years, not when it actually happened. For many analytical purposes this is sufficient. In the raw data there is a more fine-grained time scale, at least month, often week or day.

from a school/tube is of course only determined by how many years it takes to graduate.

The overall impact on the R&D institution of a stable mobility mode is nil. In any period, an age cohort *i*, whether it leaves or remains in the institution, is replaced in the next period by the equivalent age cohort ($i - 1$). This is true of all the models we consider here, simply originating in the fact that all models are based on an assumption of mobility rates being constant in time. The structural composition of the R&D staff is then stable, and, with complete inter-temporal substitutability of a given age cohort, it follows that qualitative characteristics remain constant. We take this as a realistic aspect of these models. The structure of R&D staff and modes of mobility reflects a stable equilibrium between the labour supply of graduates and other candidates to R&D employment and a stable exit of researchers to alternative employment.

This points to how mobility may have permanent qualitative or structural impacts on the performance of R&D institutions. Firstly, the associated labour supply and the related factor prices of R&D staff candidates may change. Secondly inter-temporal substitutability of age cohorts may be reduced. Lastly, the aggregate demand generating outflow of researchers. In particular, a forced increase in mobility levels would, to stay with the logic of the tube model, involve the most experienced fractile (age cohort no. *M*) of the research staff. Depending on more specified assumptions about the inter-cohort interrelations and dependencies the impact of increased mobility would vary. We note that even for mobility rates at the levels considered as policy targets, the logic of the model forces us to conclude that research careers should be fairly short, less than 10 years. Furthermore, assuming that experienced researchers dominate the processes of setting R&D strategies and project design, even a small change in mobility rates amy have disastrous impact on R&D performance by these institutions.

These aspects of the simple model have not been considered in the formulation of policy objectives and initiatives. However, it is easy to see that these conclusions are almost completely artefacts of the model, of the particular and simplistic assumptions underlying it. Thus the model essentially serves only one purpose, of demonstrating the need for an improved model.

4.2.The colinear model

A research institution is not a school, as everybody knows. Accordingly we need at least to modify the tube model to allow researchers leaving every year. To keep it simple we say that there is a given number of researches, *k*, leaving each age class every year. Thus the number of age cohorts *M* is simply given by N_0, the number of recruits, and *k*.

As with the tube model the outflow is replaced by a constant and equally sized inflow into age class 0. The overall mobility rate n/N, where *n*, the total number of research staff leaving the institution is kM, as a fraction of the total research staff. This may be expressed as very simple in terms of only *M*,

$$\text{Mobility rate} = \frac{2}{M+1}$$

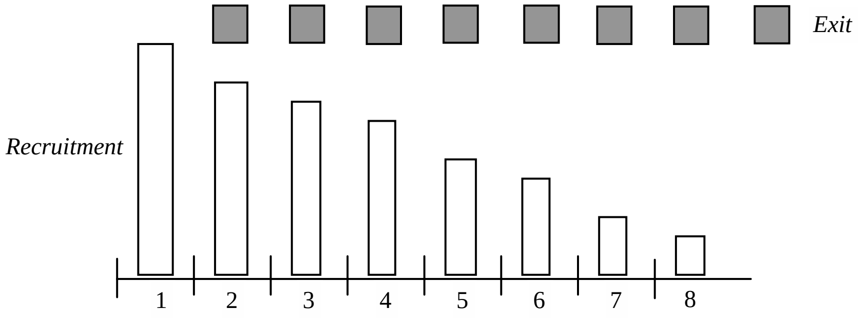

Figure 2. The colinear model for M = 8. In this case the mobility rate is 22%

Again the model may be described in terms of cohort specific mobility rates,

	Cohort 1	*Cohort 2*	………	*Cohort* M-*1*	*Cohort* M
Mobility rate	1/M	1/(M-1)	………	1/2	100%

Though slightly more complicated than the tube, this model still retains the basic simplicity of the tube and is as easy to understand. In particular, it opens up for considering heterogeneity of the mobile staff. Furthermore, it implies a more realistic span of R&D careers, for a given target mobility rate the maximum span of an R&D career is roughly twice that of the tube model.

In terms of the structure of the R&D staff of the supplier organisation this starts looking like an actual institution with a hierarchical structure. It has the further advantage of involving mobility of all age cohorts. Hence increases in mobility rates will not necessarily have the same drastic consequences as in the tube. However, it is still rather limited. In particular, all R&D careers are treated as limited. In the next section we will see that with just a minor complication we will get a substantially more realistic model.

Deliberate increases in mobility will not have the dire consequences of the former model. With the defining characteristics, mobility increases will scale down all age cohorts by the same volume, implying a reduction of the average age, and hence of quality. Though this reduction is now smaller, it affects experienced age cohorts harder.

4.3. The constant exit rate (percentage) model

The last model we introduce is a slight modification of the former one. But as we will see, altering one simple aspect of the colinear model will improve the description of the structure of R&D staff and mobility patterns. It is also readily adapted to yield more realistic descriptions and 'natural' interpretations of actual mobility patterns. Rather than focussing on the volume of transferred staff, we use mobility rates at cohort level as the basic parameter. This is more 'natural' in the sense of the rates being interpretable as transition probabilities, and hence as propensities of researchers of a certain age class to accept position in the other sectors of the economy.

We improve the colinear model with a somewhat more realistic assumption of a fixed mobility rate across age cohorts. A given share of each age class thus leaves the supplier R&D institution every year. Hence, the size of age cohorts declines gradually, asymptotically approaching zero[10].

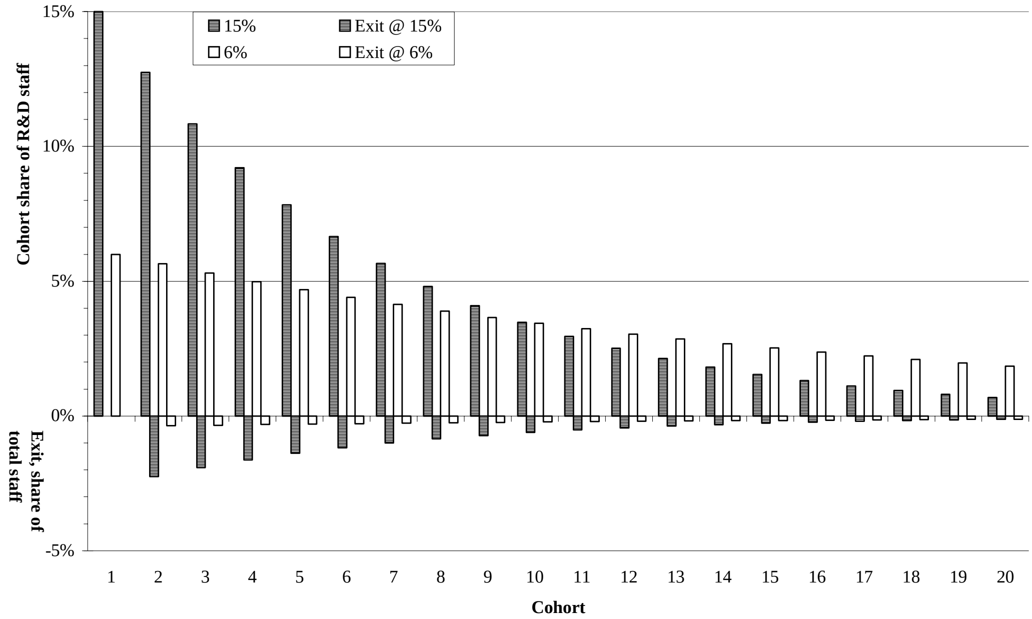

Figure 3. The constant rate model for mobility rates r *= 6% and 15%*

Mobility rates over age cohorts are constant. Hence the relative age structure of the researcher exodus reproduces the age structure of the R&D staff.

	Cohort 1	*Cohort 2*	*………*	*Cohort m*	*………*
Mobility rate	*r*	*r*	……….	*r*	…….

Figure 3 describes staff and exit for mobility rates og resp. 6% and 15%. With mobility 15% an age cohort is halved in size after about five years, with 6% mobility the half-time is about 12 years.

A table can illustrate the difference between the models. The table is constructed to compare the age structure of these three models for equal mobility rates (chosen at 20% in the table).

[10] Since we are talking about persons we must in real life operate with natural numbers. We are disregarding such minor details.

Table 1 The exit patterns of mobility models

	Tube		*Colinear*		*Constant rate*	
Cohort	*Staff*	*Exit*	*Staff*	*Exit*	*Staff*	*Exit*
1	100		100		100	
2	100	0	89	11	80	20
3	100	0	78	11	64	16
4	100	0	67	11	51	13
5	100	0	56	11	41	10
6	0	100	45	11	33	8
7			34	11	26	7
8			23	11	21	5
9			12	11	17	4
10			1	11	14	3
11+					48	14

The models have very disparate consequences for the structure of research institutions. While the tube does not even remotely resemble anything like a functioning R&D institution, the last model has an extensive tail of highly experienced staff forming the possible basis of a realistic hierarchy or team organisation of an actual R&D performing institution. How do this compare to observed age profiles of Norwegian R&D institutes?

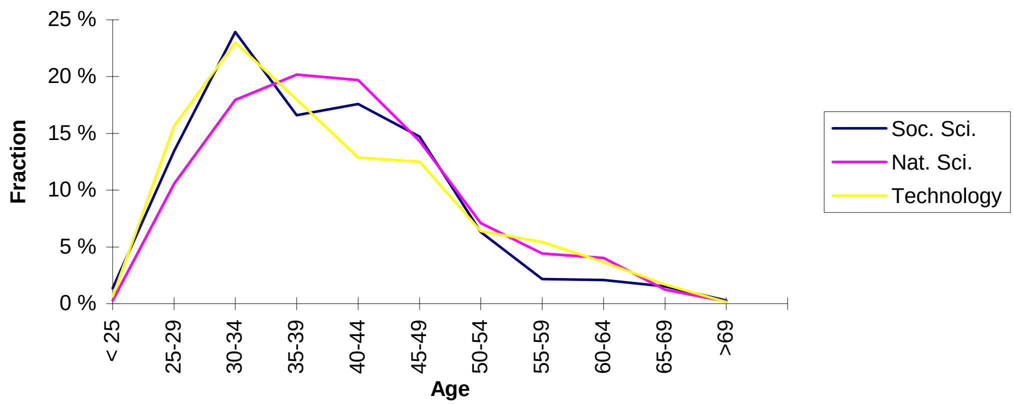

Figure 4. Age distribution of personnel in the Norwegian research institutes sector 1991. Source: Institute for Studies in Research and Higher Education, Research Personnel Register

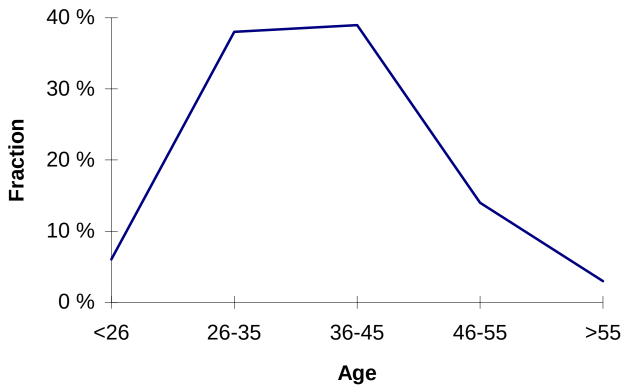

Figure 5. Age distribution at VTT institutes 1991. Source: VTT, Helsinki

The data we use here are based on researcher's physical age and length of time since her/his recruitment. The comparability of data is thus acceptable to the extent that recruitment is peaked around one certain value of physical age or at one given phase of the research career. We will discuss this further below. The age distribution of the Norwegian institutes sector in three research fields is given for 1991 in figure 4. These data may be compared to, due to data availability, somewhat coarser data, from the Finnish VTT organisation in 1991.

Three tentative conclusions may be drawn from these data. Firstly, the relative similarity in age distribution across research fields and countries seems to indicate a configuration that is fairly stable against variations in such parameters. Similarly Norwegian data for the period 1985-91 also seem to indicate a roughly time independent age distribution (see Figure 6). The final conclusion to be drawn from these data is that these distributions definitely excludes the tube and colinear models as suitable bases. It lends some support to the constant rate model, implying that within certain limits, actual mobility rates are more or less constant across cohorts.

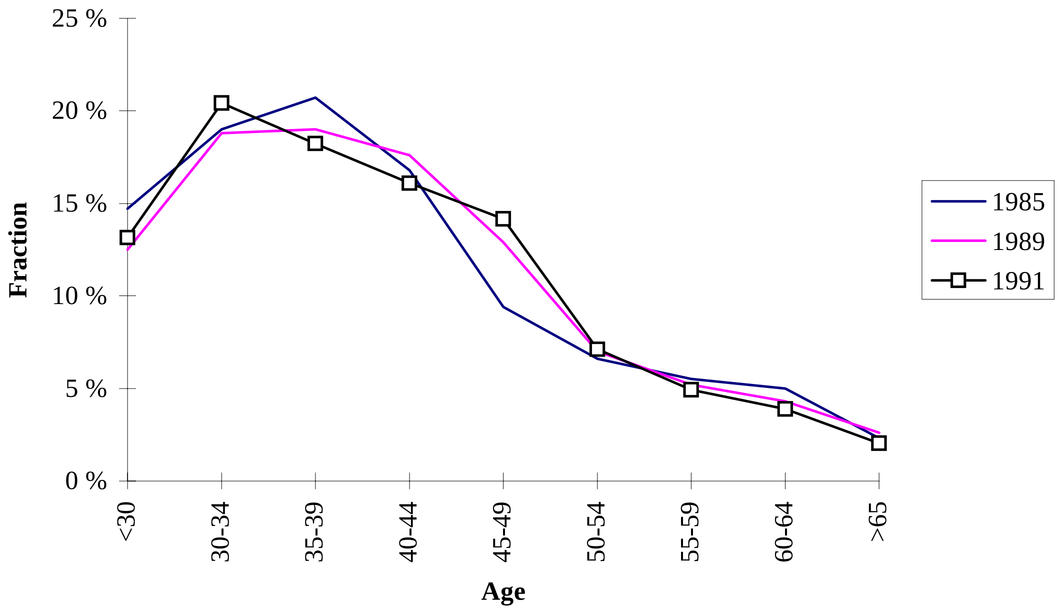

Figure 6. Age distribution as fraction of the Norwegian R&D personnel in the research institutes sector 1985, 1989 and 1991. Source: Institute of Studies in Research and Higher Education, Research Personnel Register

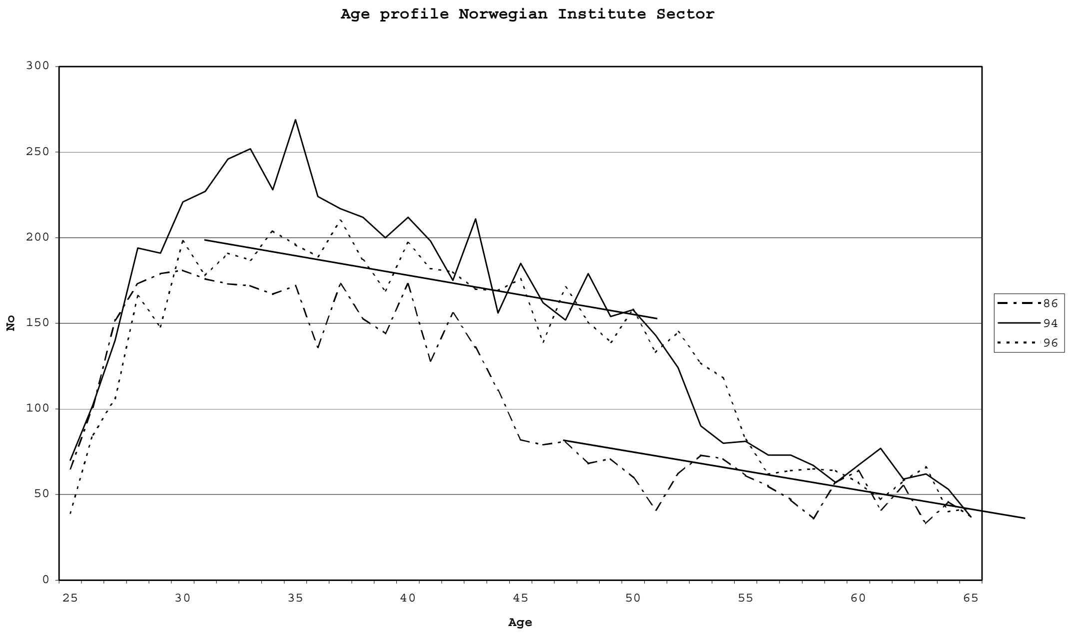

Figure 7. Age distribution of the Norwegian R&D personnel in the research institutes sector 1986, 1994 and 1996, absolute numbers Source: STEP, based on employment files from Statistics Norway

Figure 7 shows the growth of the institute sector in the period 1986-96, distributed over age of personnel. One striking phenomenon is the steep decline in the profile, located at 42 – 45 years of age in 1986, increasing to about 55 years of age ten years later. This suggests a rapid increase in the size of the Norwegian institute sector, as measured in employment, in the period 1965-75. This is indeed confirmed in national R&D data, see f.i. Hauknes (1996)[11]. This "hillside" divides the curves into two segments, but in each segment the exit rate is roughly equal and constant.

[11] Hauknes, J (1996), *R&D in Norway 1970 – 1993: An overview of the grand sectors*, STEP Working Paper 2/96

5. Toward a more general model

The final goal is to have a model based on the underlying dynamics of mobility patterns in the sense that the mobility rates are endogenously determined by the interaction of various processes. One should also try to use all the information we have about each individual researcher, i.e. his or her career. But in this paper, besides distinguishing broad fields of study, individual researchers are indistinguishable apart from (experience) age class. We talking about representative researcher of age class *i*.

5.1.Recruitment

One of the basic parameters in a general model is the number of years the individual researcher has spent in the research establishment as a measure of seniority. As we are considering specialised research systems oriented towards applied aspects of specific technological fields or for specific industries, it seems reasonable to assume that *young recruits* taken from HEIs start out with seniority 0, even though they may have some research experience from their original scientific field. Since shifts in research fields are associated with a significant decline in research productivity in the first 2-3 years after the switch[12], this seems reasonable.

In terms of Norwegian research institutes Wiig and Ekeland (1993), using questionnaires directed to the institutes, found that the newly graduated make up the single largest group of recruits, accounting for about 50% of total recruitment in 1992. One separate issue is how to treat the experience of re-entrants, i.e. people who return to a research institute after being in other jobs.

[12]A. van Heeringen and P.A. Dijkwel, **The relationships between age, mobility and scientific productivity**, *Scientometrics* **11** (1987) 267 (Part I) and 281 (Part II)

Using register data the picture becomes slightly more nuanced. For example, if we look at those who were new in 1987 (defined as not employed in the institute sector in 1986) we find that about 35% finished their education during the two preceding years. When we come to 1992 and 1996 we find that this is only the case for between 25 – 30%.

Table 2 Number of years since graduation, new employees, research institutes

Year since grad.	1987	1992	1996
0	22 %	16 %	15 %
1	14 %	13 %	13 %
2	9 %	11 %	12 %
3	8 %	9 %	12 %
4	6 %	8 %	7 %
5	5 %	6 %	8 %
6	7 %	6 %	5 %
7	3 %	4 %	3 %
8	3 %	3 %	3 %
9	3 %	3 %	2 %
10	2 %	2 %	2 %
11	1 %	4 %	2 %
12	2 %	1 %	1 %
13	1 %	2 %	1 %
14	0 %	1 %	2 %
15	1 %	2 %	2 %
>=16	11 %	10 %	11 %
	100,0 %	**100,0 %**	**100,0 %**

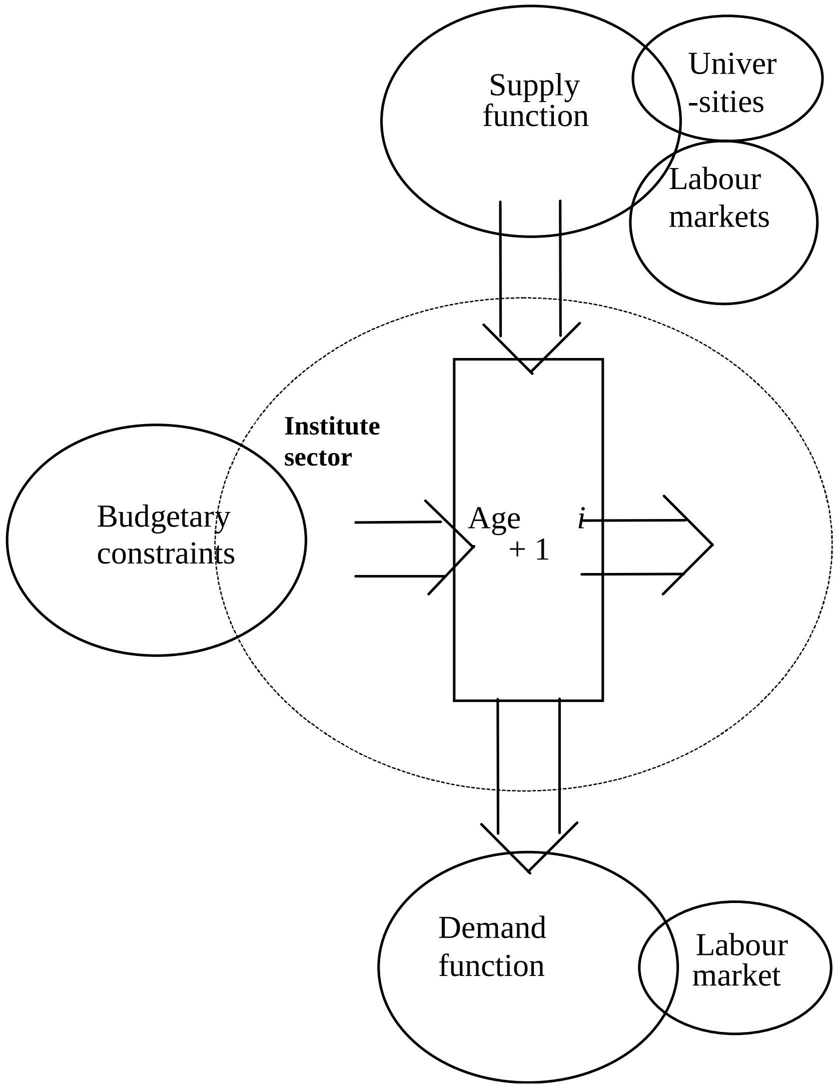

Figure 8. A model of mobility of researchers

5.2.The policy problem

The problem confronting policy makers is the simultaneous maximisation of two quality factors. The function to be maximised is dependent on recruitment, mobility and the quality and relevance of the research and researchers 'produced' in the institute sector. The problem is to find the optimal configuration of these counter-acting forces. Most problematic is how to measure the quality of research and researchers. What factors are relevant (in a mobility perspective) to this quality measurement? To approach this, let us start with some simple assumptions:

> The quality of the researcher is lowest at the beginning of their career, increasing rapidly while the researcher is young and promising, reaching a higher level and then stabilising. Subsequently slowly growing or - perhaps - declining.

There may be qualities specific to each generation, for instance knowledge of specific technologies or common cultural values.

There may be positive intergenerational effects, where a mixture of different knowledge bases have positive results. Such mixtures may be crucial in project acquisition and problem solving because innovations often simply consist of new recombinations of existing technologies and "know-hows". These technologies and knowledges are in turn modified and further developed by being used in new innovation processes. We feel that it is important to stress the teamwork aspect of research. As is often the case in sport and music, teams of composed only of star players do not necessarily out-perform more mixed teams.

5.3.Measuring quality

Measuring the "output" of individual researchers is a difficult issue that has not yet been satisfactorily solved. Looking at research institutions where the main activities are research projects financed by external 'customers', one possible measure might be project acquisition. Such data are not easily available and even if one could construct such a data set it would be questionable whether they would be meaningful, as project acquisition is more of a group phenomenon as argued above. The fact that research institutions are organised with functional differentiation between individual members, such as research directors, group leaders, senior and junior research personnel, illustrates this point.

This leaves us with various forms of peer evaluation and bibliometric approaches. The latter have become very popular, not least due to the emergence of large publication databases. But even if we choose to use publication data, with their well-know weaknesses as a 'quality index', we are up against difficulties. First of all we should use data for categories of publications relevant to the section of the RP system being considered. Evidently this refers to a large extent to publication categories outside the scope of official publication databases such as the *Science Citation Index*. In contrast to academic publications the major channel for publication is through research reports not exposed to peer-review.

Even if we could establish these data, their interpretation would not be immediate. Research activity may be unevenly distributed among researchers, with differences between ordinary researchers, group leaders, research directors and so on that are not possible to relate to their value as researchers for the system/establishment. On the contrary, at least partly it seems a reasonable conjecture that seemingly 'low-productivity' activities are associated with experience and higher value.

A partial answer to this would be to use *accumulated* publication data. Then we encounter the fact that there is evidently a wide distribution in terms of quality or degree of novelty. On the other hand one could respond that the ability to 'sell the same stock twice' should increase the value of the original breakthrough.

One way of reducing the possibility for 'double-counting' is to focus on 'academic publication' by researchers in this system, i.e., peer reviewed publication if such data could be accessible. Since this is a marginal form of publication by these researchers, relative to academic researchers, one risks losing the publication data's representativity.

However, the most important objection to the accessible data, at least in principle, is that they are given in terms of cross-section data and refer to physical age, possibly in combination with other parameters[13]. Thus we require time series, referring to shifts in research fields. At the present stage of this project it has not been possible to assemble such data sets and discuss further how these issues could be tackled.

As a proxy for data we will use cross-sectional and global publication data for the academic sector. We will use these data to limit the possibilities for index formulation, with the understanding that it is not possible to pin down any exact values. Hence any assignments of values must be regarded as conjectural.

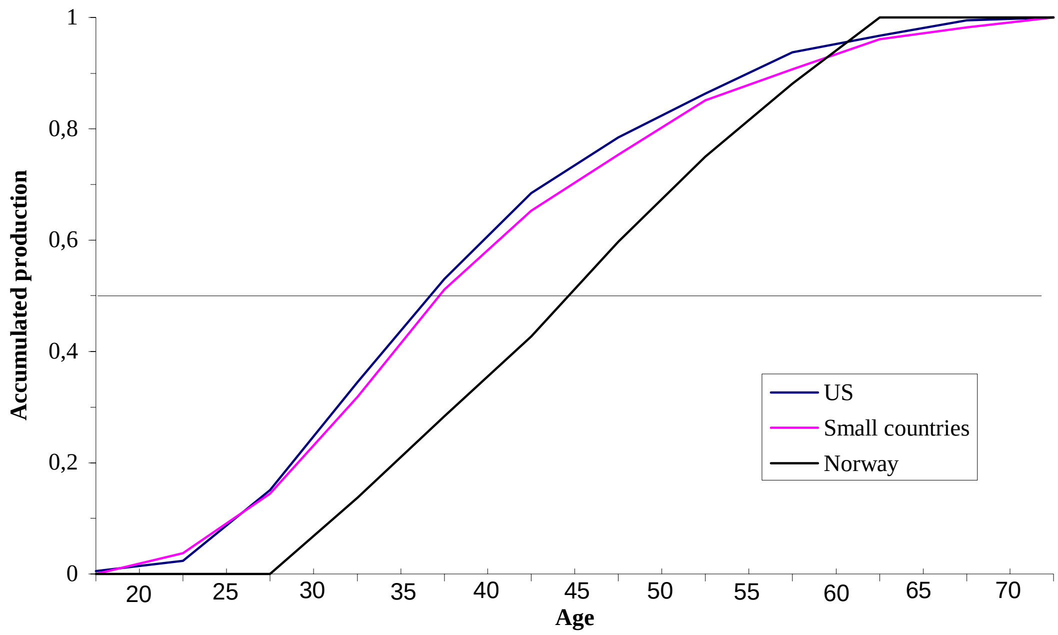

Figure 9. Age productivity relations. Source: H. Lehmann and S. Kyvik

The figure is based on two such datasets, namely Lehmann's old data from the early 50's and Kyvik's data based on the Norwegian *Universitetsundersøkelsen* [National University Survey] of 1981[14]. Whereas Lehmann's data are based on longitudinal data, the Norwegian ones are cross-section data.

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[13] See e.g. S. Kyvik, *Alder og vitenskapelig produktivitet*, TfS **31** (1990) 23

[14] H. Lehmann, *Science Monthly* **78** (1954) 321

The main limitation of the Norwegian data is that they describe the publication activities of academic researchers with a permanent position at HEIs. Thus they do not cover the period of what might be termed the 'rush for tenure', sliding the curve towards the right in the diagram.

Lehmann's data are 40 years old and hence influenced by the fact that publication differed significantly from the present regime. There are essentially two ways in which the situations differ. Firstly, available publication channels have changed considerably. In addition, the size of the research system and the number of researchers has had a sustained growth in the whole period.

The Norwegian curve is almost linear from 25-60 years, whilst the US and small countries are linear up to about 45 before starting to level off. This means roughly speaking that researchers are publishing regularly during their whole active career[15].

5.4. Intergenerational knowledge transfers

As we saw above the relative age distribution of the Norwegian research institutes sector is fairly stable over time. This may be caused by several factors including growth in the institute sector after the war, job opportunities for experienced researchers, and so on.

The Norwegian research institute sector has had a fairly constant growth of approx. 4% over a 20-year period, as measured through national R&D statistics[16]. An assumed mobility rate of about 6% in 1992, based on Wiig & Ekeland[17], indicates that about 10% of total research staff in the Norwegian research institute sector is recruited each year, corresponding to 10-15% of the annual number of awarded degrees at these levels. We shall not go into a detailed discussion whether it is meaningful to say that the demand for researchers is in balance with the supply. Our opinion is that there is no problem in getting new researchers, and that there is basically a queue of people wanting to do research. Those who do not get research jobs have no problem in getting employment elsewhere. The wages offered by the research institutes are not dramatically lower than in other sectors. If this is a correct picture then the non-pecuniary aspects of jobs inside and outside research institutes are decisive.

We argue that the qualitative feature of the distribution in terms of age parameters mirrors essential characteristics of the conditions for a dynamic research environment. That is, we view the actual age distribution as a pattern emerging on the basis of a local adaptation to the 'rules' of a productive research atmosphere.

The first 'teamwork' or rather 'network' effect we will consider is the more or less formalised supervision of junior researchers. A significant part of the learning process of younger generations at this level is through guidance and instruction from senior personnel. In the current context, the prime interest being research in

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S. Kyvik, *Tidsskrift for samfunnsforskning* **31** (1990) 23

[15] One can calibrate the parameters of a standard sigmoid curve to approach these observed accumulated curves, see Hauknes (1994)

[16] Norges forskningsråd, **FoU-statistikk 1991**, Oslo 1993. The growth refer to the number of researchers with education level ISCED 6 and above.

[17] *Op.cit.*

technology-oriented research and research in the natural sciences, we find it reasonable to use parallels to the 'training' of academic researchers. Thus we may divide the junior and median phases of a research career into two periods; a basic training, apprentice period of 3-5 years and a 'post doc' period of 3-4 years. At the end of these periods, the researcher is established at a level of tenured positions, i.e., at a senior level.

The presence of junior researchers and research assistants enhances the efficiency, and hence the 'value' of senior researchers. A considerable part of research work is of a kind that is suitable for junior researchers to carry out in order to gain experience, but which is of a routine kind for an experienced researcher. At institutions based on contract research, this is of importance both to the individual researcher and to the institution. The presence of junior researchers allows efficient use of limited resources such as experienced researchers. This is an explicit aim of contract research institutions, in terms of both project acquisition and performance. This will require an ample supply of junior researchers *qua* research assistants. In addition, as these institutions must necessarily be highly self-sufficient in terms of future experienced researchers, the presence of a stock of junior researchers is important to ensure a future supply of researchers familiar with the 'craft'.

6. The constant exit rate model

We will now take a closer look at the tube and co-linear models in comparison with a model with constant exit rate. We will describe the consequences of these three models for the physical age distribution of the population and the experience level of researchers leaving the research system.

6.1.Mean age

We have to map two time scales; ordinary age, and age meaning the years of research experience (i). University graduates with required levels of education leave for their first post at an average age of 28 years. The observed mean age of the institute sector is about 40 years, so let us for simplicity say that the mean ‘experience age’ is 10 years.

The mean experience age $\tau(t)$ at any point t in time, counting from i = 0 at graduation, of the staff is defined as

$$\tau(t) \equiv \frac{1}{N}\sum_i iN_i(t)$$

using i as cohort labels. Here $N_i(t)$ is the number of R&D staff in age cohort i at time t. This yields

$$\tau(t) = e^{-t\lambda}\tau_0 + \frac{1-e^{t\lambda}}{e^{\lambda}-1}, \quad t \geq 1 \qquad (12)$$

where $\tau_0 = \tau(t{=}0)$. The mean age increases or decreases in a transitory regime according to whether the mobility is smaller, resp. larger, than $(\tau_0 + 1)^{-1}$. Thus our first conclusion is that we would expect to see a declining mean age when $\alpha >\sim 10\%$.

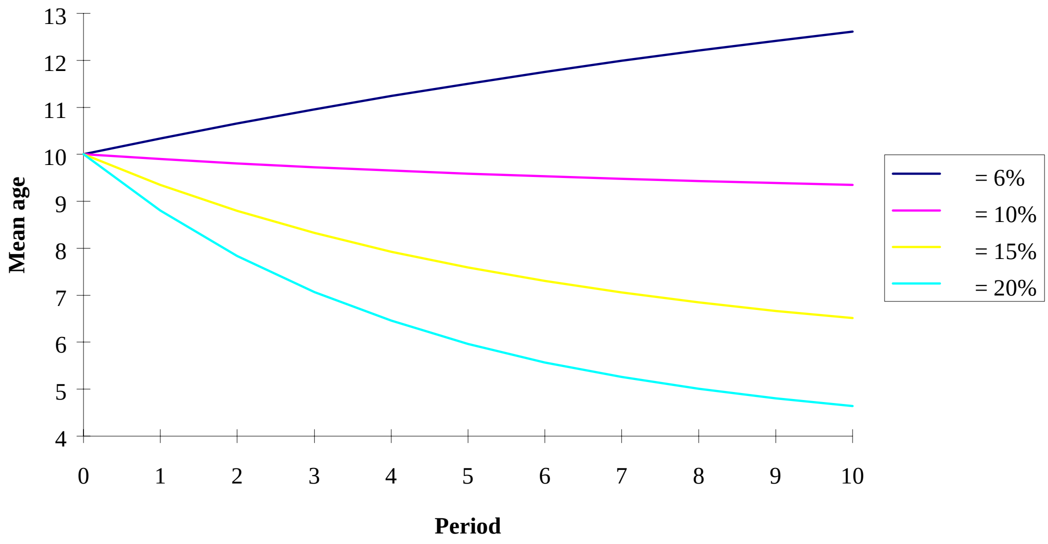

Figure 10. Mean age τ as a function of time

Similarly we may calculate the mean age of researchers leaving the population in each period,

$$\rho = \frac{1}{\delta N}\sum_{i\geq 0}(i+1)(n_i - n_{i+1})$$

For all three distributions or models $\rho = 1/\alpha$, but with a different distribution, the 'tube' distribution being a single peak, the colinear a 'white noise' distribution and the λ-distribution being left-skew.

6.2.Expected lifetimes of populations

The second concept we will introduce that characterises distribution is the lifetime of a given population. I.e., we ask the question, 'at what time t_δ is a fraction δ, $0 < \delta \leq 1$, of the individuals making up the population at time t still present?'

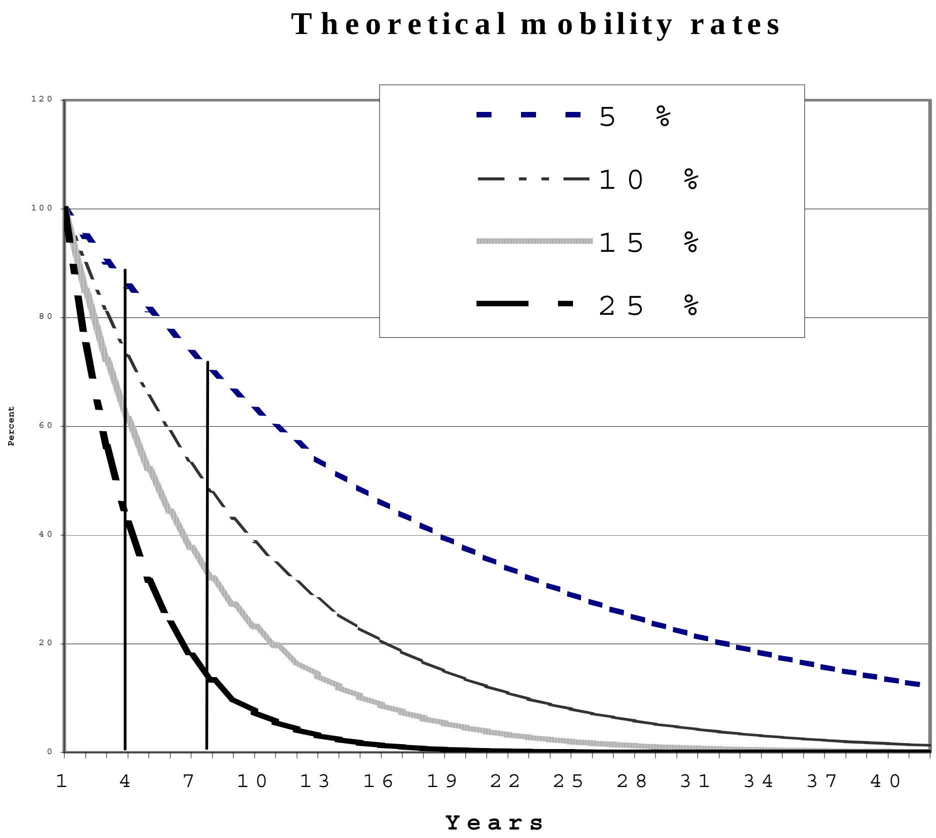

Figure 11 Life time evolution for a given age class as a function of mobility rates

The figure is meant to visualise the effect of different constant mobility rates. When the constant exit rate is 25%, there are only 40% left after four years and about 15%

after eight years; a considerable turnover! After 15 years, practically none are left. When the rate is 5% then somewhat more that 80% are still around after four years, 70% after eighth years. Roughly 15% reach retirement age in the same institute after 40 years if recruited at 30 years old. As we will se below, observed mobility rates vary considerably, from about 8 to 16%.

7. Age distribution

So far we have described 'age' in terms of the researchers age class *i*, i.e., in terms of the time passed since (s)he was recruited as a researcher into age class 0. As we saw above the empirical data are given in terms of a distribution in physical age.

We must also take into account differences in the recruitment ages in different scientific fields. We are not going into a detailed analyses here, but want to give a rough impression.

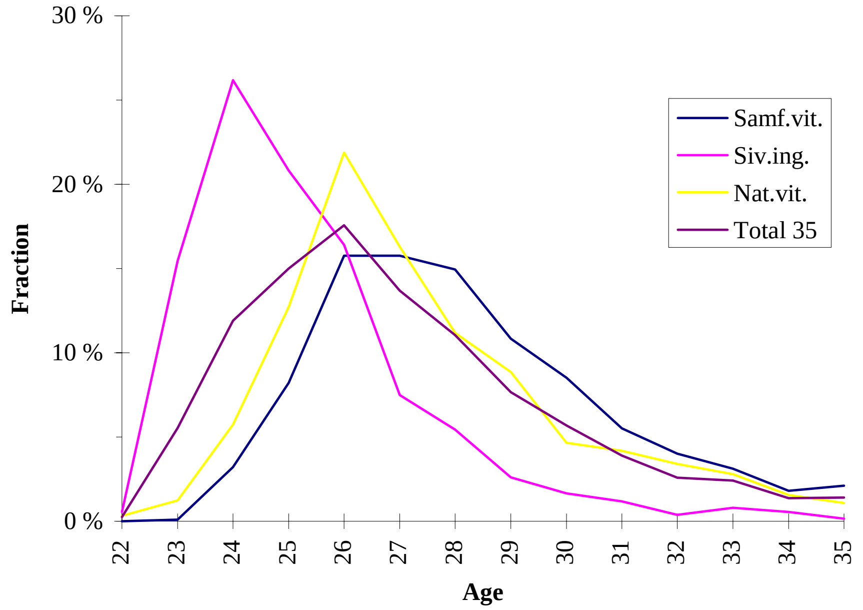

Figure 12 The age distribution of Norwegian graduates 1992. Source: Institute of Studies in Higher Education and Research, Akademikerregisteret.

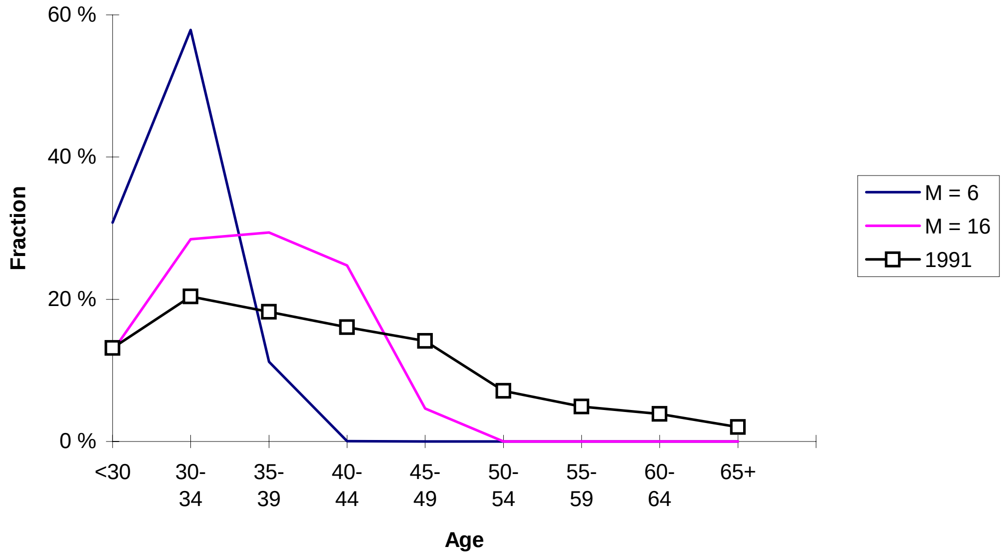

Figure 13 Age distribution in the tube model

The tube model is fully determined by the number of years, i.e. the "length" of the tube. In the figure we show two different lengths, 6 and 16 years respectively, increasing the length would approach the curve to the observed age profile.

7.1. The colinear model

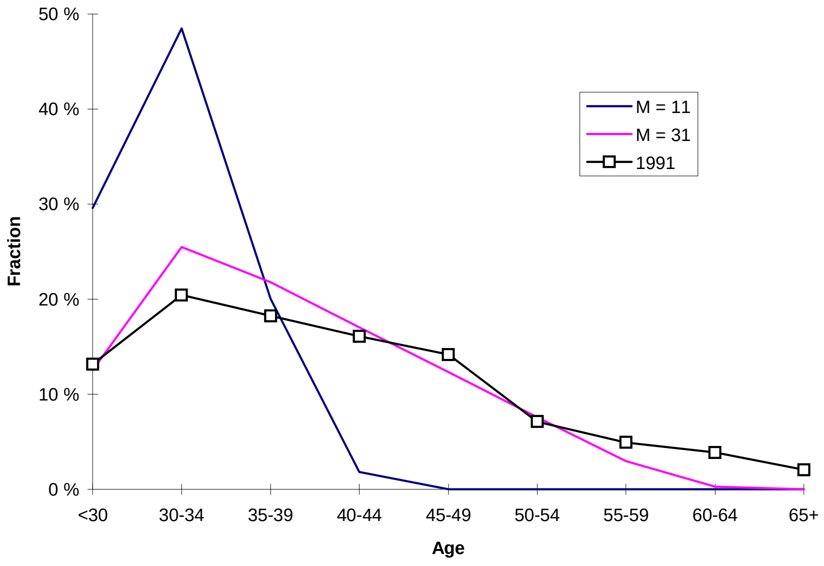

Figure 14 Age distribution of the colinear model

The age distribution is drawn in Figure 14, corresponding to the same mobility rates and based on the same assumptions as in Figure 13. With a span of $M = 31$ years, the model replicates fairly well the actual age distribution, but as is seen from the figure, the M-dependence is strong.

7.2. The constant-λ model

In this model the exit rate λ replaces the span M of the previous models as the adjusted parameter.

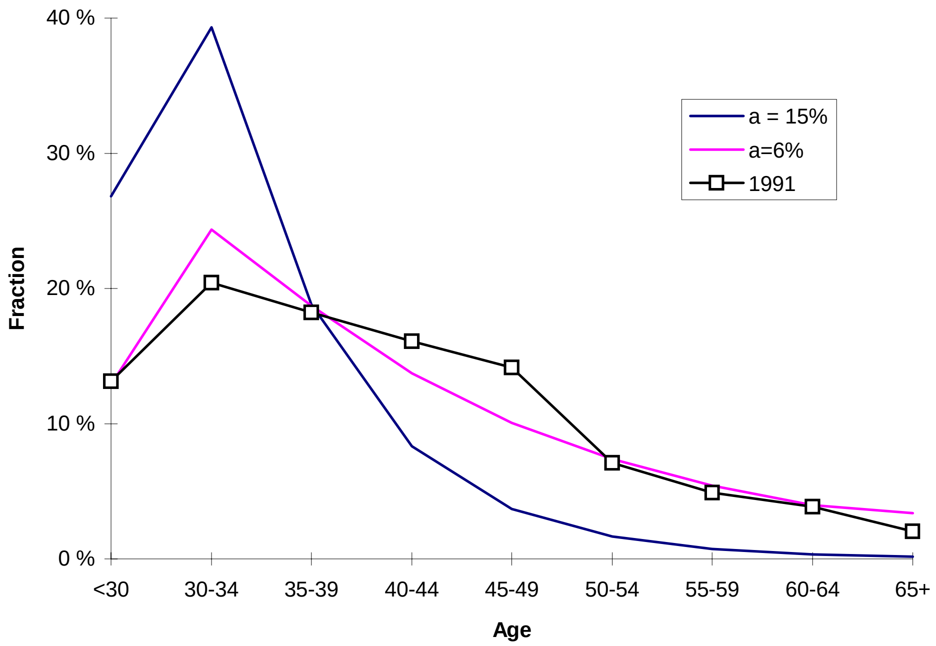

Figure 15 Age distribution of the decay model with constant λ

Even with the simple assumptions behind the model it captures the essential features of the actual age distribution. There are two important factors that may explain the deviations between the $\alpha = 6\%$ model and the 1991-data. Firstly we have assumed λ to be constant across age classes. Figure 15 would seem to imply a slightly increasing function of i up to $i \sim 10\text{-}15$ (years), turning into a decrease in later periods.

Secondly the assumption that all recruitment is at $i = 0$ is not realistic since newly graduated only account for about 50% of actual recruitment. The remaining 50% are recruitment to older age classes. To illustrate the effect of adding other recruits we can add a recruitment of experienced researchers. This is done in Figure 16, where we have added recruitment to the $i = 5$ and $i = 10$ age classes respectively in constant population model, retaining the simplicity of the original model. The parameters η and ζ measure the ratio of $i = 5$ and 10, respectively, to the $i = 0$ recruitment. All curves comply roughly with the 50-50 recruitment profile. The resulting age distributions is compared in fig. 16 to the $\alpha = 6\%$ curve from fig. 14 (η, $\zeta = 0$) and the 1991-data.

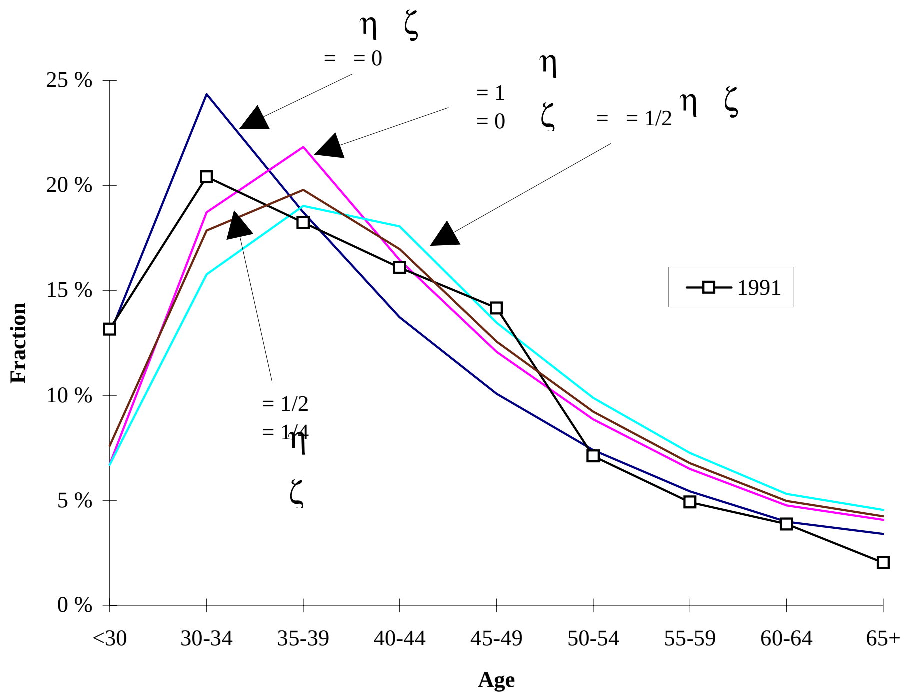

Figure 16. Age distribution recruitment of experienced researchers. Three curves are drawn, for different values of the recruitment ratios, to illustrate the effect of recruiting experienced researchers.

To conclude this section, we draw the curves for the three models corresponding to an annual mobility rate of 6%. The best fit of the constant population models is gained with the constant-λ model, a model also showing a less critical dependence on the mobility rate (compare Figures 13-15).

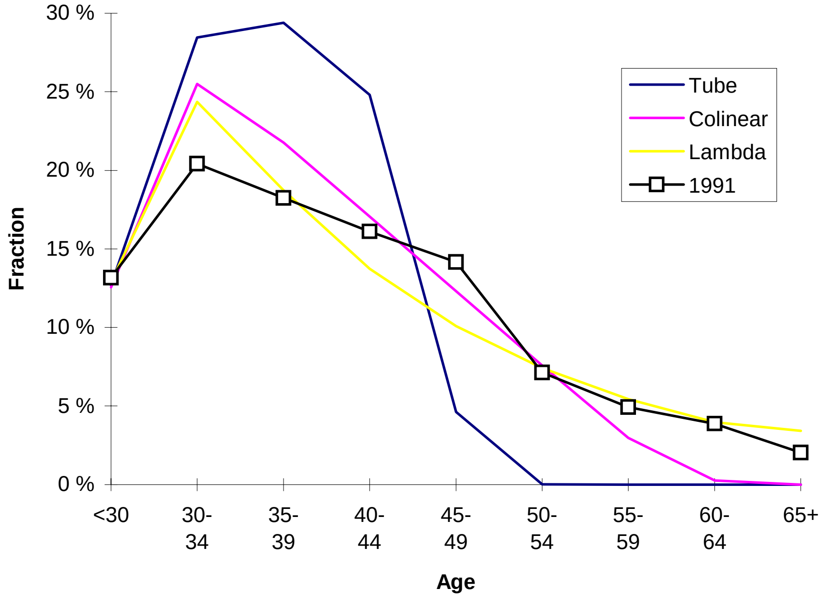

Figure 17. Model age distributions with α = 6%

7.3. The experience level of mobilised researchers

We are interested in considering mobility as a mechanism for transfer of knowledge between a research performing and a research using system. Mobility is thus not interesting in itself, rather it is competence and research skills inherent in each individual 'mobilised' researcher that is of interest. It takes time to build competence and stable networks and there is considerable difference between a junior researcher leaving after half a year and a senior researcher of 6-10 years experience in terms of both competence and the ability to maintain personal networks.

If all recruitment is newly graduated students, and if they are loyal to our simple models, then the experience level of the leaving researchers is just a reflex of the age-profile. But in real life it is of course more complicated, because the probability of leaving is not constant but depends on physical age, age when graduating and so on. We will not, however, consider these complexities here.

8. The quality index

In an earlier section we discussed how one may construct various quality indexes allowing comparison between different age distributions. Since there are few, if any, suggestions in the literature on the possible structure of such an index, and given the lack of relevant data, the following discussion is given to outline the structure of how such an analysis would be performed.

In principle, one should construct quality measures, or productivity measures, as a sum of two different effects, the increased experience/productivity of each individual researcher and a set of interpersonal and intergenerational linkages, to reflect the organisational context of the individual researcher. But as a first approximation we may just calculate the value of a researcher in a certain cohort, either as age or as years of experience. The quality score of a particular institute would then be determined simply by its age profile. Looking only at the relative share of each cohort we can study the effects on the different models.

We have used the following S-curve[18] as an illustration of a quality and productivity index,

$$Q = \frac{1}{1 + \exp(-ag)}$$

Here experience age g starts at 0, hence the "value" of the new recruits is 50%. As experience increases the quality factor Q monotonically increases to 100%. The S-curve nature implies that we have assumed a decreasing rate of return to quality, the marginal increase in quality at any point in the career of a researcher decreases monotonically towards zero. The details of the expression is not important, any other similar function would have sufficed. Even the mapping of experience (as measured by cohorts) and physical time could be loosened. We could have given each cohort a unique subjective number. The formula simply has the advantage of letting us easily vary the parameter a, a measure of the annual change in the quality factor for a cohort of researchers. The smaller a is, the less steep is the curve, and it takes more time for the researcher to get close to the maximally attainable quality. In numerical examples we have used a = 0,2 and 0,4. With a = 0,2 a researcher acquires 95% of maximum quality/productivity after about 15 years of experience, if a = 0,4 the researcher needs slightly than seven years.

In combination with different mobility rates, giving different age profiles, one can sum up the relative quality of R&D institutions with mobility rates r=10%, 15% and 25% in the constant exit rate model. One such exercise is reproduced in the table below.

[18] For a more general discussion, see Hauknes (1994).

Table 3 A hypothetical quality index

	Q		Share of staff			r=10%		r=15%		r=25%	
Y	a= 0,4	a= 0,2	r=10%	r=15%	r=25%	a=0,4 Q1	a=0,2 Q2	a=0,4 Q3	a=0,2 Q4	a=0,4 Q5	a=0,2 Q6
1	0,60	0,55	0,10	0,15	0,25	6,0	5,5	9,0	8,3	15,0	13,7
3	0,77	0,65	0,08	0,11	0,14	6,3	5,3	8,3	7,0	10,8	9,1
5	0,88	0,73	0,07	0,08	0,08	5,8	4,8	6,9	5,7	7,0	5,8
7	0,94	0,80	0,05	0,06	0,04	5,0	4,3	5,3	4,5	4,2	3,6
9	0,97	0,86	0,04	0,04	0,03	4,2	3,7	4,0	3,5	2,4	2,1
11	0,99	0,90	0,04	0,03	0,01	3,5	3,2	2,9	2,7	1,4	1,3
13	0,99	0,93	0,03	0,02	0,01	2,8	2,6	2,1	2,0	0,8	0,7
15	1,00	0,95	0,02	0,02	0,00	2,3	2,2	1,5	1,5	0,4	0,4
17	1,00	0,97	0,02	0,01	0,00	1,9	1,8	1,1	1,1	0,3	0,2
19	1,00	0,98	0,02	0,01	0,00	1,5	1,5	0,8	0,8	0,1	0,1
21	1,00	0,99	0,01	0,01	0,00	1,2	1,2	0,6	0,6	0,1	0,1
23	1,00	0,99	0,01	0,00	0,00	1,0	1,0	0,4	0,4	0,0	0,0
..	..	..	..	..	..	..	..	..	..	..	..
			100 %	100 %	100 %	88,0	79,2	83,7	73,9	77,2	67,1

Here Q1 to Q6 represent the quality factor for different combinations of exit rates and values of *a*. Not surprisingly, Q1 (at 10% exit rate, *a*=0,2) turns out to have the highest quality score. That of course results from older researchers with maximum quality being around after twenty years, whereas they have left after 15 years when the exit rate is 25%. The *a*=0,2 curve also gives relatively less value to the younger cohorts. One can note that the combination Q3 (at 15% and *a*=0,2) gets a higher score than Q2 (10% and *a*=0,4). But one should see these numbers simply as illustrations. The picture would be quite different if one said that the quality/productivity of older researchers actually declined. They might become a burden for the institute – or would they in fact have a positive impact on a firm's innovative ability?

One could of course make alternative quality indexes – based on different assumptions for both the institutes and the receiving companies. Then one could calculate the losses and gains respectively for the system as a whole. But as long as we lack a firm empirical and theoretical foundation for measuring quality/productivity of institutes and firms such exercises are too speculative to be useful. This only emphasises the fact that one should be careful about manipulating existing mobility patterns.

8.1.The RCN mobility programme 1994 - 1998

We are in the fortunate position that there has been a mobility-stimulating scheme in Norway from 1994 to 1998. The RCN has written a very interesting final report summing up the results of the programme, RCN (undated). The following information is taken from this report unless otherwise specified.

The mobility programme (MP) was a two-way programme, i.e. it supported both mobility to and from the private sector, primarily SMBs. There were four "out" and two "in" mechanisms:

Table 4 Overview over the rules of the mobility programme.

	Subsidy	No of persons
Out:		
employing researchers	50% of gross wages	13
renting researchers	50% of gross wages, at least 6 months, max 3 years	29
Post Doc. grants for research done	Gross wages in two years	12
Host for sabbatical	30-40% of gross wages	1
In:		
Master and doctoral grants	50% of gross wages, max 3 years	31
Grant for employees visiting res. institute.	50% of gross wages, max 2 years	3

In the period 1994-98, a total of 84 persons were involved in the MP; 55 went "out" and 29 "in" to a research institute. There are data on the firms/institutes the researcher worked in during the MP, but not where they went afterwards. However the report explicitly says that the researcher often did not stay in the firm, but did not go back to his/her research institute either.

Table 5 Mobility rates based on register data and data from the mobility programme

	1992	1993	1994	1995	1996	1997
Total number	1920	1952	1957	1938	1894	1874
Exit	186	165	241	199	301	288
Mobility rate	9,7%	8,5%	12,3%	10,3%	15,9%	15,4%
To business	89	62	99	93	196	195
Share of exit to biz.	47,8%	37,6%	41,1%	46,7%	65,1%	67,7%
Mobility prog. (MP)				3	5	4
MP share of exit to biz.				3,2%	2,6 %	2,1 %

As we can see there is considerable variation in mobility rates, from 8,5% to 16% over a relatively short time span. With such a degree of "normal" variation from year to year – clearly influenced by labour marked conditions, both generally and probably even more by the various segments of the labour marked – one should be careful about setting targets for mobility rates.

In addition, these rates are calculated from one year to the next, that is to say, we do not know where the researchers go next. Perhaps they return to the research institute after an unhappy stay in private companies. We know that the mobility patterns are different for various age groups. So high mobility may only be the result of a high share of "movers" that actually do not contribute very much either to technology diffusion or creating new knowledge through teamwork. To study the complicated career patterns using register data is beyond the scope of this paper, but is a question that needs further research.

The table also shows that the mobility programme had a marginal influence on overall mobility rates. This raises the question of whether the money could have been used in a better way. This is difficult to answer, because there was no system for measuring the effects on the receiving institution; there was no follow-up questionnaire asking a even a few simple questions. Such lack of follow-up is the rule rather than the exception when it comes to public support of private R&D and comes as no surprise. A programme like the MP present us with the opportunity to investigate and test the assumption that researcher mobility has a positive effect. A well designed follow-up measurement scheme would hopefully have given us a rough idea of the magnitude of the positive/negative effects. It would at least have shed more light on the negative and positive effects.

Anecdotal evidence supplied by a person involved in the programme suggests that there were several positive aspects of the mobility programme that are worth mentioning. The programme was very easy to handle for firms who were unfamiliar with how to deal with RCN. Firms could apply at any time, firms did not have to have a very detailed and impressive project plan, they could get the person(s) they wanted, and the researcher could act more as a general technological agent of change.

8.2. Where did they go?

As far as we know there has not been the intention of the RCN to do any type career analysis, i.e. looking at the individual careers of the researchers involved in the programme. Were they “movers” before becoming involved in the mobility program? What happened after the programme? Register data in principle makes it feasible to do such analysis. The report on the mobility program reports the share that went to business, but let us look at this in a bit more detail.

Table 6 Mobile researchers, receiving sectors, numbers and percent, 1995 - 1996

Unknown	46	16 %
Primary sectors, mining	3	1 %
Oil, gas and rel. services	16	6 %
Manufacturing, energy and construction	20	7 %
Trade, hotels, restaurants	9	3 %
Transport, storage, communication	4	1 %
Business and financial services, real estate	92	32 %
Research	54	19 %
Universities, other higher education	30	10 %
Public adm. and defence, health and social work	9	3 %
Other non-public services	3	1 %
Total	**286**	**100 %**

The report says that 65% went into business, which is about the same number as we get from the register data if business is regarded as a residual. That is everything except research, higher education and public administration. The rate also depends on how one treats those who are either not employed or are not found in the registers at all, 16% of the mobile technological researchers 95-96. The more detailed breakdown of the economy reveals that “Business and financial services, real estate “ and the oil and gas sector takes a lions share of the mobile researchers while traditional manufacturing gets much fewer, relative to the employment share. Manufacturing, energy and construction is more that ten times bigger in terms of employment.

If we take an even closer look at the “top ten” at the most detailed industrial classification level, this is even more striking:

Table 7 Detailed sectoral breakdown of mobile researchers

R&D natural sciences and engineering	52	28 %
Other technical consultancy	36	20 %
University education	29	16 %
Software consultancy and support	27	15 %
Extraction of oil and gas	16	9 %
Technical testing and analysis	8	4 %
Civil engineering activities	5	3 %
Data processing	4	2 %
Database activities	3	2 %
Manuf. instruments for measuring, testing a.o.	3	2 %
Sum	**183**	**100 %**

The largest group of researches leaving one of the institutes that was a part of the mobility program went to other technological institutes (private, semi-public, and public). The most popular business sectors are general technical consultancy, software development and oil and gas. The ‘top ten’ is about ¾ of all the mobile researchers exclusive the “Unknown”. So if one wants to get researcher into manufacturing, there still is a job to be done.

9. Concluding remarks

Data:
When we started our research in this area we used questionnaires, but the emergence of large public registers opens up quite different possibilities for mapping mobility and career patterns. It is very useful to have time-series on mobility rates for various groups of the workforce. We have used such data only to a limited extent in this paper, but in other contexts, among them the other reports in the FAKTA programme we have used register data to a much geater extent.

Models:
In this paper we have looked at some simple models where the main conclusion is that a naïve "the higher the better" view of researcher mobility disregards the negative impact high mobility rates can have on the research institutions. If one wishes to influence researcher mobility one should build various models, using register data to calibrate and test them before trying to implement any specific policy.

Policy:
There are certainly positive effects of mobility, and there are certainly tacit knowledges that can only be transmitted/learned by actually working together. The wandering craftsman, the travelling artist, the tradition of visiting scholars all indicate such effects. But one cannot draw from these the conclusion that levels of researcher mobility from specific institutions to other parts of society are too low without having studied the actual flows of researchers in the economy and without having thought through the long term consequences. And especially important: a mobility rate in itself tells us nothing of what we really are interested in – namely if it enhances the innovative capabilities of the society as a whole. The lack of adequate measurement schemes for measuring the effects of researcher mobility are probably the most worrying aspect of e.g. the RCN mobility programme. We have no basis for judging if the money spent on getting researchers into industry and people from industry into research institutes was wasted or not.

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STEP-gruppen ble etablert i 1991 for å forsyne beslutningstakere med forskning knyttet til alle sider ved innovasjon og teknologisk endring, med særlig vekt på forholdet mellom innovasjon, økonomisk vekst og de samfunnsmessige omgivelser. Basis for gruppens arbeid er erkjennelsen av at utviklingen innen vitenskap og teknologi er fundamental for økonomisk vekst. Det gjenstår likevel mange uløste problemer omkring hvordan prosessen med vitenskapelig og teknologisk endring forløper, og hvordan denne prosessen får samfunnsmessige og økonomiske konsekvenser. Forståelse av denne prosessen er av stor betydning for utformingen og iverksettelsen av forsknings-, teknologi- og innovasjonspolitikken. Forskningen i STEP-gruppen er derfor sentrert omkring historiske, økonomiske, sosiologiske og organisatoriske spørsmål som er relevante for de brede feltene innovasjonspolitikk og økonomisk vekst.

The STEP-group was established in 1991 to support policy-makers with research on all aspects of innovation and technological change, with particular emphasis on the relationships between innovation, economic growth and the social context. The basis of the group's work is the recognition that science, technology and innovation are fundamental to economic growth; yet there remain many unresolved problems about how the processes of scientific and technological change actually occur, and about how they have social and economic impacts. Resolving such problems is central to the formation and implementation of science, technology and innovation policy. The research of the STEP group centres on historical, economic, social and organisational issues relevant for broad fields of innovation policy and economic growth.