CPB Document

No 92

July 2005

Scarcity of science and engineering students in the Netherlands

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ISBN 90-5833-228-4

Abstract in English

Scarcity of science and engineering (S&E) graduates could potentially call for government intervention, because of the role of S&E's in R&D, and because R&D in turn is characterised by positive spillovers. In this report, we investigate whether policies that stimulate enrolment in S&E-studies are effective at increasing R&D-activity. First, we analyse the situation on the Dutch labour market for S&E graduates. We do not find evidence for scarcity of S&E graduates. Rather, the labour market position vis-à-vis other graduates weakened. A possible explanation to reconcile this conclusion with a widely felt concern of S&E shortages among employers is increasing internationalisation of the S&E labour market. Concerning policy, we argue that expanding the stock of S&E graduates is not very effective for boosting R&D activity. More than half the number of S&E graduates do not end up working in R&D. De increasing internationalisation of the S&E labour market can diminish the attractiveness of S&E courses.

Key words: R&D, education policy, science and engineering labour market
JEL code: O38, J31, H52

Abstract in Dutch

Schaarste aan afgestudeerden in bèta en techniek kan een potentiële reden zijn voor de overheid om beleid te ontwikkelen, omdat R&D gekarakteriseerd wordt door positieve externe effecten en bèta's een belangrijke rol hebben in het doen van R&D. In dit rapport onderzoeken we of het stimuleren van de deelname aan bètastudies een effectief instrument is voor het bevorderen van R&D-activiteiten in Nederland. Allereerst is gekeken naar de situatie op de arbeidsmarkt voor bèta's. We vinden geen aanwijzingen voor schaarste aan bèta's. Hun arbeidsmarktpositie verslechterde zelfs ten opzichte van andere afgestudeerden. De toenemende internationalisering van de arbeidsmarkt voor bèta's kan een verklaring zijn voor de problemen die werkgevers ondervinden bij de werving van personeel. Wat betreft beleid komen we tot de conclusie dat het vergroten van de hoeveelheid afgestudeerde bèta's weinig effectief is ter stimulering van R&D. Meer dan de helft van de afgestudeerde bèta's komt niet in R&D-banen terecht. De toenemende internationalisering van de arbeidsmarkt van bèta's kan de aantrekkelijkheid van bèta-opleidingen verminderen.

Steekwoorden: Onderzoek en Ontwikkeling, onderwijsbeleid, arbeidsmarkt voor bèta's

Een uitgebreide Nederlandse samenvatting is beschikbaar via www.cpb.nl.

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Preface

Shortages of scientist and engineers (S&E) have been on the Dutch policy agenda for many years. International comparisons show that the supply of S&E graduates in the Netherlands is low. Scientist and engineers are important in research and development. As many studies provide evidence for spillover effects of R&D-activities, shortages of scientist and engineers might hamper productivity growth. This study focuses on the role of the government in the labour market for scientist and engineers: Why should the government intervene in this labour market and which policies are the most effective?

The project was supported by an advisory committee. We would like to thank Chiel Renique (VNO-NCW), Philip Marey (ROA), Hans Corstjens and Henk van Terwisga (Platform Bèta Techniek), Hylke Niermeijer (Ministry of Agriculture, Nature and Food Quality), Lennart Nooij and Liesbeth van Dril (Ministry of Education, Culture and Science), Edi Huster and Pieter van Winden (Ministry of Economic Affairs) and Birgit ten Cate (Ministry of Finance) for constructive comments and lively discussion in the advisory committee. The comments of the advisory committee have been valuable for the project, but the analysis does not necessarily represent the views of the committee. CPB is completely responsible for the analysis and conclusions in this study. We would also like to thank Joke van de Band (VNO-NCW), Gerard Jacobs (Philips), Teun Graafland (Shell), Willie Berentsen (Vereniging FME-CWM) and Fennegien Brouwer-Key (VNCI) for their contribution to a discussion at VNO-NCW. In addition, we would like to thank Joop Hartog, Hessel Oosterbeek, Marc Pomp, Maarten Cornet and Rob Euwals for comments on previous versions of the study. Finally, we thank participants at seminars at CPB and the Ministry of Finance and other CPB colleagues for their comments.

Henk Don
Director CPB

Summary

Shortages of scientist and engineers (S&E) have been on the Dutch policy agenda for many years. International comparisons show that the supply of S&E graduates in the Netherlands is low. With approximately 7 S&E graduates per 1,000 inhabitants aged 20-29, the Netherlands scores much lower than countries like the United Kingdom, France and Ireland, which have more than 20 graduates per 1,000 inhabitants. On the other hand, the share of S&E graduates in higher education in the Netherlands is equal to the share in the US. In addition, expenditures on private R&D are relatively low in the Netherlands.

Recently, the formulation of the Lisbon targets combined with employers' concerns about the hiring of personnel intensified the policy attention for this problem. In December 2003, the Dutch government published a set of actions in the 'Delta plan beta/technology: Action plan for the approach of the shortage of science students and technicians'. While focusing on the whole 'chain of S&E', the plan aims at a 15 % increase in enrolment in S&E fields by 2007 and a 15 % increase in outflow of S&E graduates in 2010 (compared to the year 2000).

This study started from the widely felt concern about shortages of science and engineering graduates and focuses on three questions:

1. Why should the government intervene in the labour market for science and engineering graduates?
2. What do we know about supply and demand in the Dutch labour market for science and engineering graduates?
3. Which policies are the most effective?

In this study, we try to answer these questions by using the theoretical and empirical economic literature and by analysing micro data on the Dutch labour market for science and engineering graduates.

The need for government intervention

Unbalances between supply and demand can in principle be solved by market forces. So, why should the government intervene in the market for science and engineering graduates? The main economic motive for intervention in this labour market is that science and engineering graduates are important in R&D activity. Many studies provide evidence for spillover effects of R&D-activities. From a societal perspective, firms will under invest in R&D because they can not fully appropriate the returns on their investments. Hence, government interventions that increase R&D activities of private firms can raise domestic wealth. Shortages in the supply of science and engineering graduates may hamper R&D-activity and this may damage productivity growth. Government intervention in the labour market for science and engineering graduates may be legitimate to internalise the external effects from R&D-activity. The economic literature

does not provide evidence for spillover effects of S&E graduates in other activities. This does not mean that these effects are absent, but that we do not know whether these effects occur.

The current labour market

Demand

The demand for science and engineering graduates which stems from public and private R&D expenditures is quite stable. Since the beginning of the 1980s, the Netherlands spends approximately 1.9 % of GDP annually on R&D. The five large Dutch multinationals are the key players in private R&D (one third of total R&D employment). In the last 25 years, their share of the total R&D activities in the Netherlands decreased. Moreover, the Dutch share in their worldwide R&D activities decreased. This is the result of expansion of activities abroad and not the result of a relocation of activities. At the same time, other firms expanded their R&D activities in the Netherlands.

Supply

Since 1975, the number of graduates from higher education have more than doubled. The share of S&E graduates from university decreased from 28 % in 1975 to 20 % in 2002. In higher vocational education this share decreased from 22 % in 1975 to 20 % in 2002. The lower shares of S&E graduates mainly originate from a composition effect due to the increased enrolment of female students. The developments in the supply of S&E graduates sharply contrast with those of graduates in economic studies. Their shares rose by 8 %-points for university graduates and 25 %-points for graduates from higher vocational education.

S&E graduates in R&D

In 2002, one out of three S&E graduates worked in core R&D. This share has decreased by 8 %-points since 1993. R&D is primarily done by young workers; 43 % of S&E graduates between 25-29 years works in R&D against 27 % of 45-55 years. Internationalisation is important in public and private R&D. The share of foreign workers in public and private R&D is substantial and seems to be increasing. On the other hand, the share of Dutch graduates working abroad is increasing, especially S&T graduates interested in research jobs. Compared to other countries, the Dutch shares on inflow and outflow seem relatively low.

The interaction of demand and supply

To investigate the interaction of demand and supply of S&E graduates, we have looked at a wide range of labour market indicators: vacancies, unemployment rates, wages, labour market participation and weekly working hours. The main finding from this empirical analysis is that we do not find evidence for a tight labour market for science and engineering graduates in the recent past. Instead, the data suggest that the labour market position of S&E graduates has been weakening since 1996. This holds both for a comparison with all other graduates and specifically for a comparison with economic graduates.

Especially the changes in the wage level are remarkable. The wages of S&E workers have declined since 1996, compared to all other higher educated workers. At the university level, the relative wage position of S&E graduates deteriorated by 5 % and at the HBO level by 3 %. In addition, since 1979 the wages of S&E workers with a university degree have declined compared to the wages of economic graduates. While in 1979 the wage levels were about equal, in 1996 economic graduates earned 9 % higher wages. This wage differential further increased to 12 % in 2002. In the light of the lower relative supply of S&E graduates this is a surprising result, which suggests that the demand for economic graduates has been much larger than the demand for S&E graduates.

Other explanations for the wage differential are less plausible. A wage differential between S&E's and economic graduates can be related to differences in demand and supply conditions, but also to other unobserved characteristics of S&E graduates (like skills in wage negotiations). However, this explanation cannot explain a change in the relative wage level of S&E graduates over time – given that S&E graduates are comparable over time.

The fact that these labour market indicators do not provide evidence for shortages of S&E graduates poses a puzzle. How can we explain that employers experience hiring problems when all our labour market indicators suggest the opposite?

The S&E puzzle: why do employers experience hiring problems?

A possible explanation may be found in the internationalisation of R&D activities. The market for S&E graduates becomes more and more international as a large share of R&D activity is done by multinational firms. This has major implications for demand and supply of S&E graduates in the Netherlands. On the one hand, Dutch firms have access to an international supply of S&E workers and this puts downward pressure on wages because the wage level is increasingly determined in an international market. On the other hand, firms may relocate R&D activities to countries with the largest comparative advantage in doing R&D. The analysis of demand and supply provides evidence that this internationalisation process is going on. In recent years, we have observed an increase of foreign S&E graduates in Dutch universities and private R&D. At the same time, the share of Dutch S&E graduates working in R&D has decreased by 8 %-points since 1993. Moreover, the share of Dutch graduates from higher education working abroad is increasing. This is in line with a growing internationalisation of the market for S&E graduates. As a result, wages for Dutch S&E graduates will remain at the international level for S&E graduates. If this level is below the market clearing level in competing parts of the Dutch labour market, firms will have problems with hiring Dutch S&E graduates. In that case, they will have to substitute domestic S&E workers with foreign S&E workers, even if this implicates higher costs and more uncertainty about the stability of the working relation.

The other side of this story is that firms will relocate their activities if the dependence on foreign workers becomes too large. The observation that Dutch multinationals do not expand R&D in the Netherlands but abroad seems in line with this. But this can also be related with the higher economic growth in other parts of the world. In an international market firms move their activities to countries with comparative advantages.

It seems clear that internationalisation is important in the market for R&D. In addition, the labour market for S&E graduates seems more international than the labour markets for other higher educated workers. Nevertheless, it is not clear if internationalisation is the major explanation of the S&E puzzle. For instance, can internationalisation really explain that since 1996 wages of S&E workers compared to all other graduates have fallen by 5 % at the university level and by 3 % at the HBO level. Hence, we conclude that internationalisation may be part of the solution of the S&E puzzle, but we are not sure if this is the whole story.

The level of aggregation of the data

Another factor that may explain the divergence between the experiences of employers and the empirical findings is the level of aggregation of our data. In most of the analysis, we focus on the whole sample of higher educated S&T graduates. At a more disaggregated level, the picture might be different. In some disciplines it might be difficult for employers to hire graduates. In other disciplines it might be difficult for graduates to find a job. Some empirical findings are in line with this explanation. The analysis of wage differentials shows that at the higher vocational level there is a large difference in the rewards of science graduates and transport graduates. In addition, since 1991 the enrolment shares of several disciplines have changed substantially. If this explanation is important the main issue would be to improve on the match between the supply and demand of S&E graduates. This differs from the current policy targets aimed at increasing the number of S&E graduates by 15 %.

Future shortages?

Labour market forecasts indicate that the expected demand exceeds the expected supply for almost all types of higher education, including S&E studies. This is driven by the ageing of the labour force. What will be the impact on R&D activity? First, R&D is typically done by young employees. Occupations with a relatively young work force will be less affected by the replacement demand induced by workers that are retiring. As such, the replacement demand for R&D workers may be smaller than in other occupations.

Second, the impact on R&D activity will also depend on the changes in competing parts of the labour market. Relative scarcity of S&E workers in the future is more informative because this determines relative wages and thereby influences enrolment decisions and choices of job type. The predicted vacancy rate in S&E studies is lower than in some other disciplines at both higher vocational and university education. As a consequence, we may expect that market forces are stronger in attracting students and graduates to non-S&E types of education.

In addition, the internationalisation of the labour market for S&E graduates will prevent the wages of S&E graduates to adjust to changes in domestic scarcity, which may reinforce the decrease of the relative demand for S&E graduates. This could undermine the wage prospects of S&E graduates even more.

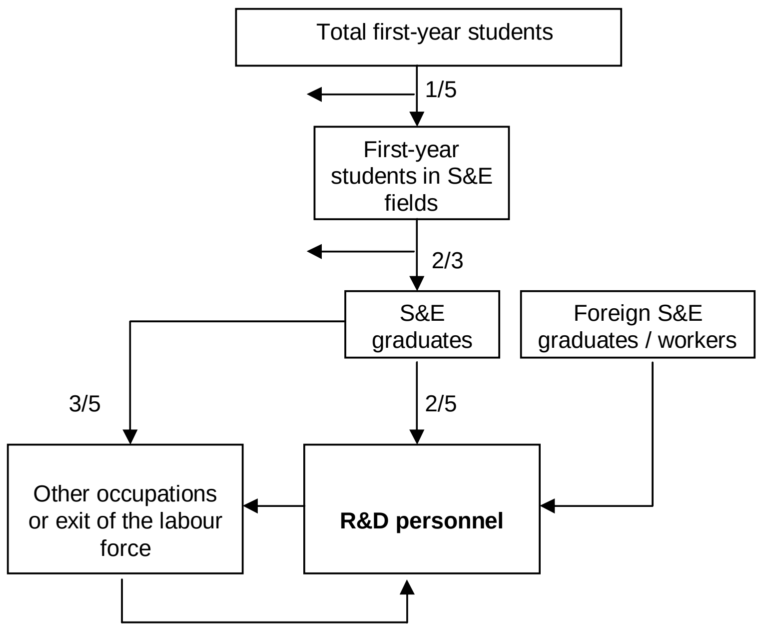
Which policy is the most effective for increasing R&D-activity?

Spillover effects to other economic activities legitimate government intervention to increase R&D activity in the Netherlands. But which policies are the most effective for increasing domestic R&D-activity? The government can try to increase R&D activities with supply side policies and with demand side policies. Supply side policies focus on increasing enrolment and graduation in S&E studies. Typical instruments are financial incentives (lower tuition fees) or projects aimed to increase interest in technology (like making R&D or research jobs more attractive) or to promote the graduation rate in S&E studies. Demand side policies focus on the demand for R&D by private firms. Typical instruments are R&D subsidies, like the WBSO. The choice between supply side and demand side policies depends on the degree of government failure.

Government failure

Not all government instruments are successful in realising the targets that are aimed for. This so-called government failure is important for both subsidising the demand and supply side. However, the effectiveness of demand side polices seems to be much larger than the effectiveness of supply side policies. The main reason is that demand side policies are directly targeted at increasing R&D activity whereas supply side policies generally are not. Several steps have to be taken before supply side policies, like school projects aimed at changing educational decisions, translate into an increase of R&D. This is illustrated in Figure 1.1 which shows the supply chain from university or HBO to R&D-jobs.

Figure 1.1 The supply chain from education to R&D



Approximately 40 % of all S&E graduates end up in a job in R&D. Hence, subsidies on enrolment in S&E studies are not well targeted and about 60 % leaks away in the supply chain. This leakage of resources will be smaller if S&E graduates, who do not enter R&D jobs, also enter jobs with spillover effects. However, the external effects of S&E graduates in other jobs are unknown. Demand side polices, in contract, focus directly on an increase in R&D-activity. In addition, the time between the subsidy and the increase in R&D is much smaller for demand side policies. For supply side policies to be effective it takes at least several years because graduating from S&E studies takes time. Demand side policies can not only increase R&D activity but can also increase the attractiveness of S&E studies.

International dimension

The internationalisation of R&D production will lead to an efficient relocation of S&E workers and R&D firms. What does this mean for the effectiveness of demand and supply policies which aim at increasing domestic R&D? In general, international forces can change the elasticities of demand and supply for R&D which changes the effectiveness of policies. For instance, opening up international labour markets for R&D workers will make it easier for firms to actually find such workers if demand increases. This increases the effectiveness of a subsidy on the demand for R&D. Another consequence of the internationalisation of the supply of R&D workers may be that domestic supply side policies become less effective. Suppose that the government wants to make S&E education more attractive relative to other studies. As a result of the internationalisation, domestic S&E workers have to compete with a growing influx of cheaper foreign S&E workers. The growing competition of foreign workers makes it less attractive to enrol in S&E studies which undermines the effectiveness of supply side policies.

And even if students enrol in S&E studies they may not take R&D jobs if other jobs are more attractive, in term of wages or other aspects. If internationalisation of R&D production causes the market clearing wages for R&D workers to fall below that of other professions, the only effective way to stimulate S&E graduates to choose R&D jobs is to subsidies those *jobs*.

Policy options

The ‘Delta plan bèta-techniek’ is a mixture of interventions aimed at various targets. The main motive for government intervention in the labour market for S&E graduates can be found in the spillover effects of R&D production. Hence, the main target of these government interventions should be to increase R&D-activity in the Netherlands.

1. Define policy in terms of R&D objectives.

The case for demand side policies is stronger than the case for supply side policies. Demand side policies are directly targeted at R&D production whereas supply side policies are not. Even if supply side policies succeed in increasing enrolment in S&E studies, graduates might choose not to work in R&D if other jobs are more attractive. Hence, a large share of the supply side subsidies will leak away in the supply chain. The internationalisation of the labour market for R&D workers further reduces the effectiveness of such policies.

2. Be cautious with supply side policies, because there might be a lot of government failure.

The government failure with supply side policies will be smaller if there are also external effects of S&E graduates in other activities than R&D. However, there is no empirical evidence on this and there is also no empirical evidence on external effects of graduates from other disciplines. The empirical literature on labour supply suggests that the elasticity of the decisions on the type of job and the number of hours worked is higher than the elasticity of enrolment in education. Policies that focus on more elastic margins will suffer less from government failure. Hence, the government failure will be smaller for interventions further down the supply chain such as ‘attractive jobs’ and ‘attractive location’.

3. The effectiveness of the current policy program ‘Deltaplan beta-techniek’ can be enhanced by increasing the emphasis on interventions further down the supply chain like ‘attractive jobs’ and ‘attractive location’. Instruments that focus on the most elastic margins of the decision on the supply of labour – working more hours in S&E jobs and on choosing between working in R&D and in other jobs (e.g. through special tax credits for S&E workers) – are the most effective.

The current knowledge on the impact of supply side interventions is very limited. There is no convincing evidence on the impact of various projects which aim at increasing enrolment and graduation in S&E studies. Moreover, private firms actively support these projects. A sensible way to approach in this context, could be to generate knowledge on the impact of these projects. This can be done by choosing experimental designs for the various public - private initiatives and evaluating their impact. If the government wishes to stimulate supply with various projects aimed at increasing enrolment and graduation in S&E studies:

4. Formulate policy measures in such a way that they can be evaluated and that credible evidence can be generated on the impact of various projects.

For instance, to find out to what extent participation in S&E courses can be boosted with additional grants, a controlled experiment can be done. In this experiment a randomly selected group of final-year secondary school pupils is offered additional student grants, whereas a control group is not. The effect of the additional student grants can then be measured by comparing the participation in technical courses in the experimental group with the participation in the control group.

1 Introduction

The problem of a shortage of scientists has been on the agenda for decades. Godin (2002) describes how the particular demands on the labour market from the war efforts in World War II lead to systematic discussion about and measurement of highly qualified personnel. Since then, potential shortages particularly of scientists and engineers have often been forecast.

This is no different in the Netherlands. The last 15 to 20 years concerns have been voiced over possible shortages of students in science subjects. Indeed, students seem to loose interest in science and engineering (S&E) fields. While in the 1950s about 30 % of the first-year university students enrolled in an S&E related-field, this share declined to approximately 25 % in the 1970s and around 20 % today. Confronted with this downward trend, companies and politicians have regularly voiced concern about a potential shortage of S&E graduates. In reaction to this, in December 2003 the Dutch government published a set of actions in the 'Delta plan beta/technology; Action plan for the approach of the shortage of science students and technicians'.[1] The plan is aiming at increased enrolment of S&E students.

This government intervention raises several questions. First, why is the government intervening in the labour market for science and engineering graduates? In principle, market forces will solve unbalances between supply and demand: shortages of supply will induce higher wages and this will attract new students. The answer to this question can be found in the special role that science and engineering graduates play in the knowledge economy. These graduates are potential employees in research and development (R&D) professions. In turn, R&D plays a key role in the 'production' of innovations which is, according to modern economic growth theory, an important determinant of economic growth. This contribution to economic growth is explained by spillovers: positive external effects that enhance the productivity of the economic process at large. In economic theory it is well known that external effects can be a justification for government intervention. Hence, the aim of intervening in the labour market for science and engineering graduates is to increase R&D activity in the Netherlands. This brings the second and third question. Does the current situation on the Dutch labour market for science and engineering graduates hamper R&D-activity? Is increasing the supply of science and engineering graduates an effective method of increasing R&D-activity? This study focuses on these questions.

The analysis consists of three steps. First, we will briefly look at some economic theory, to make explicit the possible need for government intervention, and to form some hypotheses about what we would expect to find in the empirical analysis. Second, we will look at the data on the current labour market situation. What do we know about supply and demand for science and engineering graduates and how does this relate to R&D-activity? Although most of the data

[1] See OCW (2003). The plan will be further discussed in chapter 2.

bear on the recent past, we will also look at the available labour market forecasts. Third, we will look at the effectiveness of policies aiming to increase the R&D-activity. How effective are supply side policies in increasing R&D-activity?

2 The problem

The concerns over the shortage for science and engineers are based on a comparison of shares of S&E's with other countries, general trends towards a more knowledge intensive society, signals from companies and universities who resort to hiring foreigners and the R&D ambition as part of the Lisbon agenda. Supply in the Netherlands is indeed low compared to other countries, although not declining rapidly.

2.1 Current numbers

In this study, S&E graduates are defined as all students from university and Higher Vocational Education (HBO), who received a diploma in one of the following fields: life sciences, physical sciences, mathematics and statistics, computing and engineering. In the data analysis in chapter 6, agriculture is also counted as an S&E field.

S&E workers are a sub sample of the group of knowledge workers. Table 2.1 below gives a rough idea of the numbers involved. The concepts used in the table are discussed further down.

Table 2.1 Make-up of the Dutch labour force, 2001 (x 1,000 persons)

	Whole population	With higher education
Labour force[a]	7,921	1,894
of whom knowledge workers (HRST)[b]	3,268	1,894
of whom in HRST professions	2,964	1,590
of whom managers	241	241
of whom specialists	1,345	1,039
of whom technicians and assistants	1,378	310

[a] International definition, all persons working more than 1 hour per week.
[b] HRST: Human Resources in Science and Technology.
Source: CBS, Kennis en Economie 2003, table 2.5.1. Note: these numbers roughly correspond to NOWT (2003) data.

Knowledge workers are, according to the 'Delta plan beta/technology', "everybody with a degree in higher education and all others, mostly those with intermediate vocational education, who play a catalytic role in innovative processes" (OCW, 2003, p. 9). This definition comprises nearly half the Dutch work force. It includes scientists, but also most economists and people working in fields like law or journalism. OCW (2003) stresses the fact that these people 'are all necessary to come to innovation and higher productivity growth'.[2]

[2] The above definition is related to the definition of Human Resources in Science and Technology (HRST) as described in the so called Canberra manual of the OECD. It combines two different dimensions: education and profession. OECD (1995, p. 16) states that "HRST are people who fulfil one or other of the following conditions: (1) successfully completed education at the third level in a Science & Technology field of study; (2) not formally qualified as above, but employed in a Science & Technology occupation where the above qualifications are normally required."

In this study, we are particularly interested in a sub sample of knowledge workers, and we use a narrow definition of what is comprised in Science and Technology (S&T). The OECD opts for a broad definition, in which science means knowledge or knowing, and technology means the application of knowledge. Here, using a narrow definition, we focus on those who received higher education in the fields of science and engineering (S&E). This means we identify them by their education, rather then by occupation. Following the definition of the European Commission[3], the fields of education in S&E are:

- Life sciences (biology and other bio-sciences);
- Physical sciences (physics, chemistry);
- Mathematics and statistics;
- Computing;
- Engineering (including engineering trades, manufacturing and processing, architecture and building).

Broader definitions often include health (e.g. medicine, nursing) and agriculture (including forestry and veterinary sciences) within the S&E fields. We focus on the core fields of exact sciences and engineering, since health and agriculture are usually not part of the fields that are considered to be problematic. However, in the data analysis we do include agriculture in our S&E definition, due to restrictions in the EBB database (see appendix).

The definition by education also applies to attained educational level. We focus on higher education, which in the Netherlands comprises university and Higher Vocational Education (HBO).[4]

To get a feel for the number of graduates from science and engineering fields, see Table 2.2. In section 5.3 we take a closer look at the development of the number of graduates over the last 25 years. In the table below we also included the group of economists, because apart from using

[3] Table A.3 in EC (2003) is particularly useful in defining S&E, also in relation to the ISCED nomenclature.

[4] In the definitions above of HRST and S&E workers we speak of different educational levels. The classification usually applied to (internationally) compare education levels is the International Standard Classification of Education, the so called ISCED 1997 nomenclature (UNESCO, 1997). ISCED is also used by the OECD and the European Commission, and ranges from pre-primary education (level 0) to advanced degrees (level 6). In this classification higher education is defined as programmes falling into ISCED5 and ISCED6, where ISCED5 stands for the first stage of tertiary education and ISCED6 for the second stage, being advanced research programs (PhDs). Within ISCED5 we can distinguish between level ISCED5A, being long-term degrees (minimum 3 years), and ISCED5B which includes only short-term degrees (less than 3 years). (In addition to education *levels*, ISCED also contains a classification of education *groups or fields* of education. This way, it is clearly defined which educational programmes can be referred to as science or engineering programmes.)
Higher education in the Netherlands is made up of so called HBO, which we will refer to as higher vocational education (HBO; HBO-schools refer to themselves internationally as Universities of Professional Education), and universities, also referred to as WO. In general, HBO schools offer mostly vocational degrees, and universities offer mostly degrees with a more academic emphasis. The Netherlands have very few degrees of type ISCED5B. Most short-term students are generally of MBO (intermediate vocational education) level (ISCED3), whilst for many other countries they are counted in ISCED5. In the Netherlands, the level ISCED5A corresponds therefore to university (WO) and higher vocational education (HBO).

the total population as a reference group, we also focus on the comparison with economists. We will elaborate more on this in later chapters.

Table 2.2 Outflow of graduated students in higher education in the Netherlands, x 1,000 persons

	1997/'98	1998/'99	1999/2000	2000/'01	2001/'02
University	22.7	20.8	20.8	20.8	21.7
of whom science and engineering	4.9	4.4	4.0	4.1	4.3
of whom economics	3.6	3.7	3.4	3.6	3.8
Share of S&E	21%	21%	19%	19%	20%
Higher vocational education (HBO)	42.7	43.4	44.8	44.6	46.2
of whom technical fields	9.8	9.6	9.7	9.5	9.4
of whom economics	11.9	12.8	13.3	13.4	14.5
Share of S&E	23%	22%	22%	21%	20%

Source: CBS Statline

What is considered R&D?

In later chapters, we will partly shift our focus to a particular activity which S&E workers can perform: research and development (R&D). R&D is defined in the Frascati manual (OECD, 2002a, p. 30), as "creative work undertaken on a systematic basis in order to increase the stock of knowledge (…) and the use of this stock of knowledge to devise new applications." Of the people who conduct R&D, two groups are regularly distinguished: research scientists and engineers (RSEs) and technical and associated professionals. RSEs are "engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned." (OECD, 2002a, p. 93).

Table 2.3 R&D workers in the Netherlands, 2001 (x 1,000 full time equivalents)

R&D workers in companies	48
of whom researchers	22
of whom technicians and assistants	18
of whom others	8
Research staff at universities and related institutions	27
of whom researchers	16
of whom in science and engineering (incl. agriculture and health)	11
of whom technicians and assistants	0
of whom others	11
R&D workers in government financed research institutes (not being universities)	14
of whom researchers	7
of whom in science and engineering	6
of whom technicians and assistants	4
of whom others	3

Source: CBS, Kennis en Economie 2003, tables A.3.1.2, A.3.2.2. and A.4.1.5; CBS Statline.
Note: these numbers roughly correspond to NOWT (2003) and OCW (2003) data.

R&D workers are identified by their occupation, rather then their education. The Dutch equivalent of the International Standard Classification of Occupation (ISCO) is the SBC92 (*Standaard Beroepenclassificatie* 1992), which is being used by CBS (Statistics Netherlands). The SBC distinguishes between different levels of occupations: low (first digit: 1-5), high (6-7) and scientific (8-9). The second digit indicate the sector of occupation. We classify within the category ‘core R&D occupations’ the sectors: 2nd digit SCP 4-8 (agriculture, mathematics and physics, engineering, transport) and within the category ‘broad R&D occupations’ the sectors 2nd-digt SCP 0 (other occupations) and SCP 8 (managers).

In 2001, R&D-personnel constituted about 3 % of the S&T labour force. About half of these R&D-workers are RSEs.

2.2 The problem from the perspective of the policymakers

In policy, special attention is being devoted to science and engineering in higher education, and to the S&E job market. These efforts stem from the perception that a shortage in the S&E work force is already a fact or an eminent possibility. A summary of the analysis behind these concerns, from both business and government, is given in the report ‘No knowledge workers, no knowledge economy’ (‘*Zonder Kenniswerkers, geen kenniseconomie*’), which is published together with the ‘Delta plan beta/technology’. The report analyses the market for knowledge workers and S&E graduates in particular. After analysing these, the report signals an increasing discrepancy between demand and supply of S&E graduates. We will here shortly discuss these factors.

Supply of S&E graduates

The report signals a concern about the low supply of S&E graduates. This is particularly based on a comparison of the Netherlands with other industrial countries. Data from the European Commission show that the Netherlands falls far behind Germany, France and UK in terms of the percentage of S&E graduate students out of the total population. With about 10 S&E graduates per 1,000 of male population aged 20-29 (7 for males and females together in that age bracket), the Netherlands falls in the lowest group together with Italy. Finland and Ireland are in the leading group with both more than 20 S&E graduates per 1,000 inhabitants in the age bracket 20-29. Further, while other countries show an increasing trend like UK, France or Italy, the number of S&E graduates in the Netherlands over the 1993-2002 period remains fairly stable at a low level. The low numbers are not a new phenomenon. For the United States, data are only available for the earlier years.

Table 2.4	Number of male S&E higher education graduates per 1,000 males in the age of 20-29 (ISCED5 and ISCED6: short-term, long-term and advanced research programs)							
	Ireland	Finland	France	UK	Germany	Netherlands	Italy	US
1993	26.6	20.8	19.8	18.3	13.2	8.9	3.6	15.4
1994	28.7	20.8	-	19.3	14.2	9.0	3.5	16.2
1995	29.5	20.8	-	19.4	14.9	9.3	3.6	16.4
1996	28.4	20.7	-	20.2	14.8	10.8	5.2	16.6
1997	28.1	23.6	24.5	20.4	14.4	-	5.7	-
1998	29.2	23.7	25.4	21.1	13.7	9.9	6.2	-
1999	-	26.1	26.4	21.5	13.2	9.5	6.7	-
2000	28.6	22.7	27.1	21.4	12.6	9.5	7.1	-
2001	27.4	24.6	28.3	25.6	12.2	10.0	7.6	-
2002	28.3	-	-	25.5	12.2	10.8	-	-

Source: Eurostat (Structural indicators - Innovation and research).

However, the numbers in Table 2.4 should be put into perspective, as these data include both long-term and short-term high-level education. Therefore, the high score of a country can for some countries be explained by a large number of short-term tertiary degrees, rather than long-term ones.[5]

Because of the possibly distorted image due to short-term degrees, it is complemented by Table 2.5. Also in this table, the Netherlands falls into the last group. This table contains data of the OECD (2004) on the share of S&E graduates enrolled in long-term and advanced research programs in higher education (ISCED 5A and ISCED 6). In total, less than 20 % of Dutch students enrol in S&E related fields, while this percentage is 42 % in Korea and around 33 % in Germany. The Netherlands, together with the United States, Denmark and Norway, score below the OECD average of 26 %.

Table 2.5	Share of S&E graduates per field of study out of the total student population in higher education (ISCED5A and ISCED6, 2002)						
	Engineering, manufact. & construction	Physical sciences	Life sciences	Mathematics & statistics	Computing	Agriculture	Total S&E
Korea	27.4	3.5	2.1	1.9	3.5	2.6	41.0
Germany	17.6	5.0	3.4	1.7	3.3	1.9	32.9
Finland	21.6	2.0	1.4	0.6	3.4	2.2	31.2
France	12.5	4.9	5.8	2.5	3.0	0.3	29.0
Netherlands	10.7	2.2	1.0	0.3	1.8	2.4	18.3
USA	6.3	1.4	3.7	0.9	3.4	2.3	18.0
Norway	7.4	1.1	1.1	0.2	5.1	1.2	16.0

Source: OECD, Education at a glance 2004 (Table A4.1)

[5] See the definition of higher education earlier in this chapter.

Table 2.5 shows how students are distributed within the different S&E related fields. A few countries like Korea or Finland compensate their relatively low levels of students in physical and life sciences by a large number of engineers. France, instead, exhibits a rather large number of students in exact sciences, with just more engineers than in the Netherlands. The picture for Germany looks rather balanced, combining high scores in every field. The Netherlands, however, seems to show no strong fields with low scores in every field.

Demand for S&E graduates

As for the demand for S&E graduates, the report first signals an increasing demand for knowledge workers in general in the coming years, on the basis of general trends and surveys. Then it complements this demand with the policy ambitions from the Lisbon agenda, boiling down to the ambition to raise R&D efforts in the Netherlands from the current 2 % of GDP spending to a future 3 %. The report concludes thereupon that if this ambition is to come true, there will be a shortage of R&D personnel.

International comparison of S&E shortage perception

How is the problem of a shortage of S&E workers perceived, compared to other countries? The Global Competitiveness Report 2004/2005 from the World Economic Forum is a useful source for a quick comparison.[a] The tables in the report are compiled using the Executive Opinion Survey, which is a questionnaire among business executives and entrepreneurs in large number of countries and across industries. The data report on the perception of the interviewed executives, as they compare their country in relation to other countries. Scores are from 1 to 7, and a relative ranking is made among about 100 countries.

Dutch managers rate the technological readiness of their country rather high: a 5.0 average, which ranks the Netherlands at position 20. The quality of scientific research institution is considered high (position 11), as is company spending on research and development (position 10). In comparison, subsidies and tax credits for firm-level R&D are still above average, but the Netherlands captures position 18.
The rank on the availability of scientists and engineers is remarkably low: position 36. The score is still relatively high (5.0) and just above average, but the ranking is rather on the low side. The same picture emerges in the perception of education: quality of schools ranks in the top 20, but quality of math and science education ranks position 24. Finally, the ease of hiring foreign labour is still considered below average: the Netherlands ranks position 70.

It must be stressed that survey data are difficult to interpret. Since cultural backgrounds differ among countries, the answers are not always comparable. Also, the absolute scores are often not widely dispersed, which makes a ranking rather volatile. Note however, in addition, that 'hard facts' in international comparisons, particularly relating to R&D and innovation, also have their interpretation difficulties.

[a] Reference is made here to tables 3.01 to 4.11.

Also, the report signals that the last years, the number of R&D labour years has increased by 2 % per year. This is seen as a signal of a strong and increasing demand for S&E graduates.

Further, universities have been recruiting a large number of foreign students to fill up PhD vacancies in S&E fields. The same goes for companies. The report takes this as a signal of a strong demand that cannot be met by the current Dutch supply. Indeed, firm surveys reveal that companies find it more and more difficult to find qualified personnel in S&E fields.

2.2.1 The 'Delta plan beta/technology'

The report '*Deltaplan bèta/techniek; Actieplan voor de aanpak van tekorten aan bèta's en technici*' was presented jointly by three Dutch government departments, namely the Ministries of Education, Culture & Science; Economic Affairs; and Social Affairs & Employment. The expected future shortage of knowledge workers, and in particular people in science and engineering (S&E), is the point of departure of the 'Delta plan beta/technology'. The long term goal is to have more employees contributing to innovation. The medium term goal is a 15 % increase[6] in outflow of S&E students in 2010 and 15 % higher inflow in 2007. Also higher inflow of women and the immigrant population, and more foreign students and knowledge workers.

Special attention is given to the whole chain of S&E: the full path of education through to attracting, keeping and utilising knowledge workers on the labour market. The idea is that the government, educational institutes and employers have to work together. Four main lines of action are identified:

- Attractive education: more attractive technical studies all round and less drop outs;
- Attractive jobs: jobs with an appealing perspective;
- Attractive choices: improving image of S&E jobs and fields of study, and experimenting with monetary incentives to coax students;
- Attractive locational factors: removing obstacles for foreign knowledge workers to come to and stay in the Netherlands.

Some of the core measures of the 'delta plan' include experimenting with lower tuition fees for S&E students, promoting research jobs and relieving barriers to immigration for knowledge workers. Attention is largely devoted to higher education, but the Deltaplan also focuses on intermediate vocational education (MBO). Both the supply side of S&E workers are targeted (mostly through measures the government can take) as well as the demand side (mostly through measures business can take).

[6] In the aim of the Deltaplan the 15 % increase is related to student flows in 2003 (p. 16). In the calculation of the student numbers necessary to meet the 15 % increase, it is related to student flows in 2000/2001 (p. 17).

Some examples of policy action taken, following from the Deltaplan

The ‘Action programme Platform beta/technology’ contains further details on the concrete short term actions that will be taken to execute the Delta plan. The programme lists 22 actions, focussing on all levels of education (primary, higher and vocational), on attractive jobs and attractive choices. These actions together give insight on where funds are spent in 2004-2005. The total sum spend in 2005 is 15 million euro.

A number of actions aim at renewing the way S&E education is done. For instance for primary and secondary education, funds (2 mln euro) are being directed to subsidise schools to guarantee solid and structural attention for S&E in the educational programme. The ultimate aim would be a change in the choice patterns of youngsters. Likewise, funds (1.3 mln euro) are available to reassess the curriculum for S&E subjects in the upper classes of high schools, and perhaps to develop one new, overall S&E subject. The curriculum at universities (bachelors degrees) are also under scrutiny, and talks are being set up to explore the possibilities to include more social context or multidisciplinary elements in the S&E programmes (0.4 mln euro). In the same vain, the trajectory of vocational education (lower, intermediary and higher) is being redesigned as for the S&E content (1.7 mln euro. The main instrument is to work with pilots, institutions who make an effort towards renewal, and later build on the best practices from these pilots.

As an example of an action focussing on attractive jobs, 3 mln euro is devoted to so-called public/private mobility, especially with respect to R&D. The idea is that career perspectives can be more interesting in S&E fields, if businesses and the public sector (research and education, mostly) exchange more experiences and people. An example aiming at attractive choices is science and engineering communication (1 mln euro). The money is available as a subsidy for various organisations, which should perform activities that make S&E education more attractive.

In some cases, the way the money is spent takes the form of an experiment, or a pilot. However, as far as can be understood from the action programme, the design of these experiments don’t seem to give opportunity for a solid quantitative assessment of the effectiveness of the actions taken.

The available funds for the ‘delta plan’ are 6 million euro in 2004 up to a maximum of 60 million euro in 2007. As a back of the envelope thought experiment, assuming the full 60 million is spend in 2007, we can calculate the costs per additional student, or more interestingly, per additional R&D worker. Using a quick and dirty calculation, the costs per additional R&D worker is 150.000 euro.[7] The costs per additional R&D worker change if other assumptions are made. For instance, the above calculation assumes 800 additional S&E graduates. If instead we assume that the ‘delta plan’ increases S&E outflow on a structural basis, then the subsidies up to 2007 also generate additional R&D workers after 2010. The figure of 800 would then have to be much higher, which means average costs per R&D worker are lower.

[7] A 15 % increase means an increase from roughly 14.000 graduates in 2001 to 16.000 in 2010. About half of those are already in the baseline projections, for which no additional policy is required, which leaves about 800 graduates extra to be achieved by these policies. This comes down to 75.000 euro additional cost per graduate (60 million euro divided by 800 graduates). If we were to very roughly assume that about half of these graduates move on to work in R&D, this would imply each R&D worker would have to contribute about 150.000 euro in additional social returns, at which figure the cost-benefit analysis for society would break even.

Policies before the 'Deltaplan beta/technology'

Before the Deltaplan was presented, various policies already existed or had been tried, which are aimed at science and engineering. A number of efforts have been made in the past through advertisement campaigns, to improve the image of S&E courses of study, particularly for women. The aim was increased enrolment. Other measures are not directly related to enrolment, but show special attention and extra funds for technical fields of study.

For instance, universities receive higher funding for students in S&E courses. The compensation a university receives from the central government for education (rather then research) is for more than 60 % based on student numbers (both enrolment and number of graduates). Science and engineering students yield roughly 1.5 times higher yearly payment than other students (apart from medical students, who yield 3 times higher payment). For HBO institutions the difference between funding for S&E and non-S&E students is smaller (OCW, 1999). These policies are usually attributed to the higher cost of these specific courses, especially the costs of laboratory environments and materials. Also, students are allowed longer course duration for S&E courses. This implies extra costs for the government because the eligibility for student grants is based on official course duration. This policy is usually attributed to the degree of difficulty of the courses, or to efforts aimed at the quality of courses, to put it differently.

In 1998, the government together with various groups within education and business decided to establish a special platform - Axis - whose aim was to stimulate the supply of S&E graduates on the labour market. The mission of Axis is to identify a series of best practices that can effectively increase the enrolment into S&E fields. Projects are organised along three main lines: influencing choices of pupils and students in early stages of the education system (in primary and secondary education); proposing a new design for the teaching of S&E fields (in secondary and higher education); making S&E careers more attractive. A lot of these best practices ended up in the 'Deltaplan beta/technology', which was launched in 2003.

3 Economic rationales for government intervention

Many studies provide evidence for spillover effects of R&D-activities. From a societal perspective, firms will under invest in R&D because they can not fully appropriate the returns on their investments. Hence, government interventions that increase R&D activities of private firms can raise domestic wealth. Shortages in the supply of science and engineering graduates may hamper R&D-activity and this may damage the growth of productivity of the economic process at large. Government intervention in the labour market for science and engineering graduates may be legitimate to internalise the external effects from R&D-activity. The private return to higher education roughly equals the social rate of return at current levels of government expenditures on higher education. The case to further subsidise the supply of skilled workers in general is rather weak.

3.1 The supply of S&E workers and economic growth

Human capital in general, and science and engineering students in particular, are believed to contribute in a non-trivial way to economic growth. In the standard neoclassical growth theories, a higher level of education increases effective labour input and hence raises steady state income per capita (Mankiw, Romer and Weil, 1992). First-generation endogenous growth theories suggest that increasing levels of human capital may prevent decreasing returns to capital accumulation and may get the economy on a faster growth path (Romer, 1986, Lucas, 1998). In the second-generation growth theories, human capital is the most important input in R&D activities which are, in turn, the engine of economic growth (Romer, 1990; Jones 1995).

Some early empirical findings by Murphy et al. (1991) suggested that countries with a higher proportion of engineering graduates grow faster than countries with a higher proportion of law graduates who are associated with rent-seeking activities. Hence, it is not surprising that policymakers who want to promote economic growth are concerned with the supply of skilled workers.[8]

More recently, it is beyond empirical dispute that human capital has a large private rate of return.[9] The private returns are estimated to be in the order of 7-9 %, i.e., gross wages increase 7-9 % with every additional year of education. However, in spite of very suggestive initial findings on the importance of human capital for growth,[10] a growing body of empirical evidence nowadays suggests that education does increase the level of income per capita but not the growth rate. More importantly, the private rate of return to higher education roughly equals

[8] Sianesi and Van Reenen (2002) state that the findings of Murphy e.a. are not very convincing.
[9] See for excellent overviews Card (1999) and Harmon, Oosterbeek and Walker (2003).
[10] See Murphy et al. (1991), Barro (1991), Mankiw et al (1992), Benhabib and Spiegel (1994), Barro and Sala-i-Martin (1995).

the social rate of return at current levels of government expenditures on higher education.[11] This would imply that in the current situation all external effects are internalised: additional education for educated workers will not generate external effects to less educated workers and workers fully receive the returns on their education. Therefore, the case to further subsidise the supply of skilled workers in general is rather weak. From a policy perspective, this could be the end of the story: current evidence does not suggest that the supply of human capital falls below the socially desirable level.

However, these are analyses based on averages: does the same hold for the case of S&E workers? S&E workers are the most important ingredient for R&D activities. Through this link, there might be a case for government intervention. The central question then is: do these R&D activities generate spillover effects to other activities? That is, do the benefits to society exceed the benefits reflected in the salaries of R&D workers?

3.2 The supply of S&E workers and R&D

Science and engineering workers may increase growth or income through the process of research and development. According to (semi-)endogenous growth theories as developed by Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992) and Jones (1995), the stock of S&E graduates is an important determinant of the innovative capacity of a country, because the supply of R&D workers determines the total amount of R&D activities which can be carried out. R&D in turn generates technological change and increases in economic growth or income per capita.

From the labour market statistics we can indeed establish the importance of S&E workers for R&D. According to data from the Dutch Labour Market Survey 2002, S&E graduates represent 56 % of all human resources working in core R&D occupations. They also form the largest group of researchers since 75 % of all high educated personnel working in core R&D occupations has an S&E background. Due to their prominent role in R&D occupations, the stock of S&E graduates is believed to be an important determinant of R&D. Again, the question is, does R&D matter for growth? And, more importantly, is government intervention warranted?

[11] See also Heckman and Klenow (1997), Acemoglu and Angrist (1999), Krueger and Lindahl (2002), Sianesi and Van Reenen (2002), Ciccone and Peri (2002) and many others.

3.3 Positive R&D externalities

R&D (research and development) may generate positive external effects, also called 'spillovers'. R&D creates benefits to a wider group of people or firms than to those who are actually involved in R&D activities. These external effects occur because knowledge which is *codified* in technologies, ideas and patents, has the characteristic of a public good. First, knowledge technology can be easily copied and reproduced (technology is non-excludable). Even patents protect only part of the knowledge embodied in a technological innovation (and for a limited time); the rest can be freely used by others. Second, using the technology does not make it more difficult for others to use it as well. In other words, several persons can use a technology at once (technology is non-rival). Due to these specific properties, the knowledge created through R&D by one agent can 'spill over' to many other agents in the economy. Economists say therefore that the social returns to R&D are larger than the private returns. Because R&D firms can not charge for these spillover effects the incentives for investing in R&D are less than optimal. The market fails, in the sense that the suppliers of R&D can not fully appropriate the returns on their activities.

The literature distinguishes between diverse types of positive external effects:

- Knowledge spillovers: one company learns from the efforts of other companies.
- Network spillovers: the returns on R&D investments in one company increase when another company invests in R&D (complementarity).
- Market spillovers: the buyer of a new product gets the product for lower costs than the old version of the product (high price-quality ratio).

The literature also pays attention to negative external effects related to R&D:

- Patent-races: companies may duplicate technologies in a patent-race and this leads to a waste of costly resources.
- Business stealing effect: new products may make old products quickly obsolete (Aghion and Howitt, 1992).[12]

The empirical literature generally supports the claim of substantial positive external effects. [13] Due to methodological difficulties the range of outcomes in the literature is rather large.

[12] Past innovators lose profits when other firms introduce new products. If past innovators take into account the possibility of dynamic competition the difference between private and social returns will be smaller.

[13] For a discussion of this literature see Nadiri (1991), Griliches (1992), Mohnen (1996), Cameron (1998), Canton (2002) en Cornet (2001).

However, overall, the positive effects seem to more than compensate the negative effects. The major conclusions of this empirical literature are:[14]

- The private returns to R&D are generally estimated around 15-30 %.
- The external effects are manifest and quantitatively important at all levels of aggregation (firm, sector, region, country).
- The lower boundary for external effects is found to be at about 25 % of the private returns.
- External effects on R&D are not only present at the national level but also at the international level. Firms and sectors in the home country benefit from R&D efforts of firms and sectors located abroad.
- Foreign external effects diminish with the (physical) distance between the home country and the countries abroad. The external effects of foreign R&D are therefore smaller than the effects of national R&D (per unit R&D).
- The literature gives no clear picture regarding the nature of the R&D spillovers (knowledge, network or market). They all appear to be relevant.
- Conducting R&D in a firm, sector and country matters in order to benefit from external effects of R&D in *other* firms, sectors and countries (particularly in small open economies). This is referred to as the absorption capacity argument. It implies that a minimum level of R&D is necessary to benefit from R&D done elsewhere (Cohen and Levinthal, 1990).

Hence, the main conclusion from the empirical literature is that the returns to R&D are high, both at the private and social level. This raises the question why firms and countries do not spend much more on R&D. The literature does not answer this question. A factor that may be important in this respect is risk. R&D projects are characterised by many uncertainties, for instance about the possible applications of the project, the demand for the new products and the activities of competitors. In addition, governments that try to increase the level of R&D activity may encounter a lot of government failure (see section 9.2). Another issue is the wide range of the empirical findings. As mentioned before, estimating the returns to R&D is difficult because of methodological problems, such as the measurement of R&D spending.

S&E workers in non-R&D professions

A fair share of S&E graduates end up working in non-S&E professions. In turn, of those working in S&E, a large part do not work in R&D occupations. They might work in occupations related to the R&D core activities, such as distribution or other activities further down in the product chain. Obviously, from a business point of view, these activities are necessary to benefit from the R&D investments. However, as regards the role of the government, the question is whether these non-R&D-activities are characterised by positive spillovers? In other words, are the social returns higher than the private returns. The empirical

[14] Empirical evidence for the Netherlands confirms those conclusions (Jacobs, Nahuis en Tang, 2002).

literature does not provide any evidence for this, which means that to our knowledge there are no studies on this subject.

3.4 Policy intervention

Our discussion thus gives a legitimate rationale for government intervention in research and development. The private returns of R&D lie below the social returns to R&D because of external effects to R&D activities. Therefore governments may want to develop policies that increase R&D activity. However, these policies may not be effective if the R&D capacity of the country is insufficient because there are not enough S&E workers who can perform R&D tasks. If there is a shortage of R&D personnel, Goolsbee (1998) shows that promoting R&D activities will result in higher wages of R&D workers, reducing the policy impact on R&D volume. In that situation there might be a case for promoting the supply of R&D personnel. It is therefore of crucial importance whether there is sufficient supply of workers with an S&E background. The next chapters will touch upon this question.

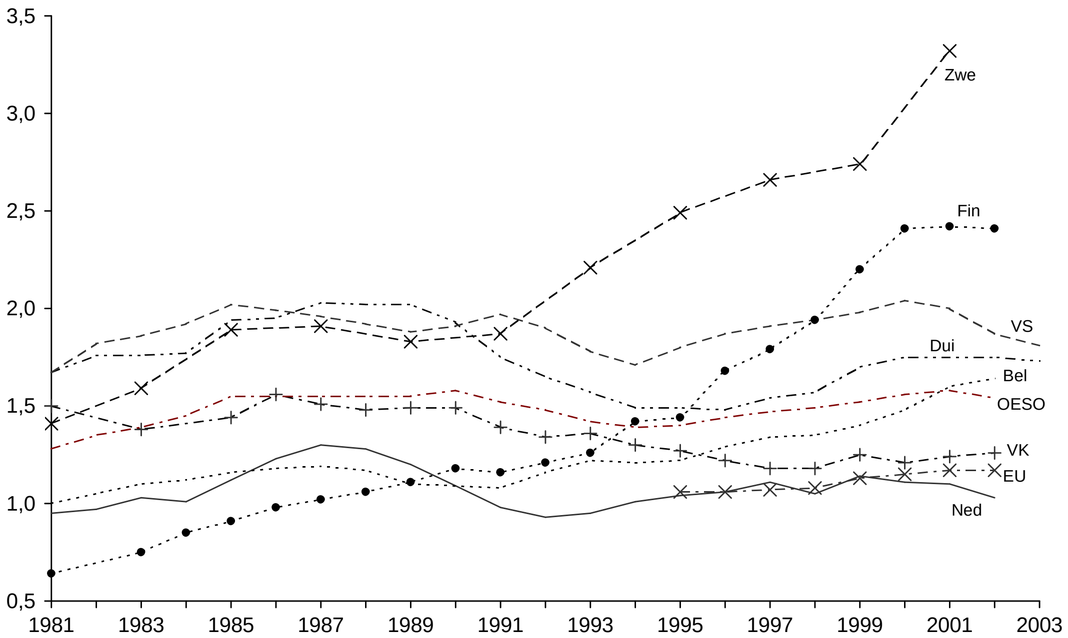
4 The demand for S&E graduates

The demand for S&E graduates which stems from public and private R&D expenditures is quite stable. The five large multinationals did not relocate R&D activities from the Netherlands, but their expansion of R&D takes place in other countries. The share of total R&D activities in the Netherlands carried out by the big five decreased as a result of an expansion of R&D activities of other firms in the Netherlands.

4.1 Expenditures on private and public R&D

Private expenditures on R&D are relatively low in the Netherlands. Figure 4.1 shows that the R&D intensity of Dutch firms lays below the R&D intensity of the major large countries and below the EU average.

Figure 4.1 R&D expenditures of companies, in % GDP

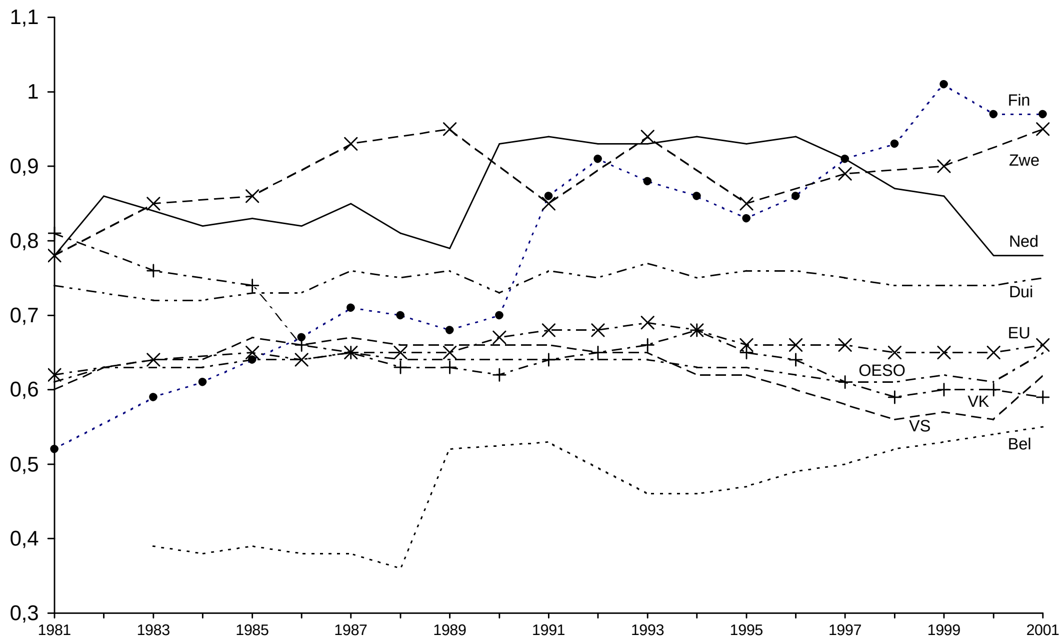


Source: OECD Main Science and Technology Indicators 2004/1

The low R&D expenditures of the Netherlands are related to the sector structure or specialisation pattern of the country. The Netherlands has little specialisation in R&D intensive sectors (pharmacy, computers, automobile, non-electric machines, etc). This sector effect explains 28 % of the GDP lag of the Netherlands (see CPB, 2002).

The picture is quite different if we take into account the (semi-)public expenditures on R&D. The share of R&D done by the public sector (universities but also public research organisation) is relatively high in the Netherlands (see Figure 4.2).[15]

Figure 4.2 Public R&D expenditures, in % GDP



Source: OECD Main Science and Technology Indicators 2004/1

Over the last 25 years the R&D expenditures as a percentage of GDP spent on wages and thus on R&D personnel has remained stable. Hence, there is no evidence that a larger part of R&D expenditure has been spent on machines rather than personnel in the last decades.

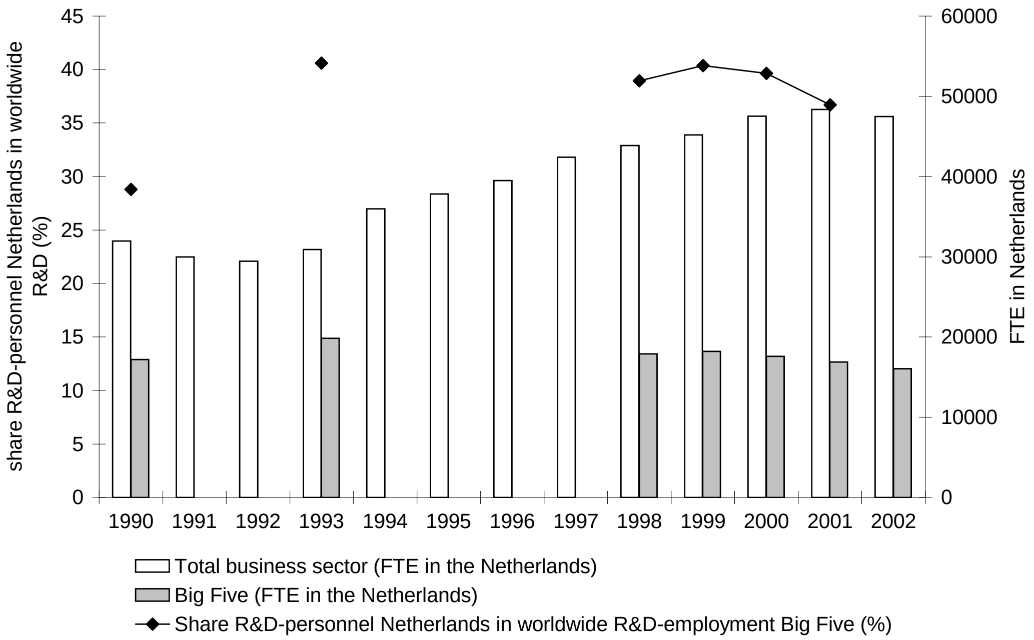
4.2 Relocation of R&D production?

The production of R&D becomes more and more international as a large share of R&D activity is done by multinational firms. Firms may relocate R&D activities to countries with the largest comparative advantages in R&D production. CPB data on R&D-expenditures and -personnel of the five large Dutch multinationals (the Big Five) show that there is little evidence for relocation of Dutch R&D-activity to other countries in the past 25 years.[16] In 2002, the Big Five accounted for about one third of R&D-personnel (fte) in the Netherlands. Their share decreased over time, but this was mainly because R&D-activity of other, smaller or foreign, firms increased (Figure 4.3).

[15] Note that although business R&D is mostly in S&E fields, larger parts of public R&D are also in social sciences and humanities.

[16] Akzo Nobel, Philips, DSM, Shell, Unilever. Data source: CPB company database, April 2004; see also Cornet and Rensman (2001) for an extended analysis, and Rensman (2004) for an update of the data.

Figure 4.3 R&D-personnel Big Five and other firms in the Netherlands



Source: Rensman (2004).

The number of R&D-workers of the Big Five at their Dutch and foreign locations fluctuates by firm and over time (Table 4.1). The share of R&D-personnel at Dutch locations compared to total worldwide R&D-personnel of these five multinationals together decreased in the past 10 years (Figure 4.3). This is the result of the growth of R&D activities abroad, such that the share

Table 4.1 Big Five: share of Dutch R&D in the company's world-wide R&D, 1977-2000

	1977	1980	1985	1990	1995	1999	2000	2002
R&D-personnel								
Akzo	60		32	34	34	52	54	51
DSM	100		100			82	80	70
Philips					45	43	39	36
Shell	50		35	29		34	40	
Unilever	26		16	13	12	18	18	18
R&D-expenditures								
Akzo	61		44	52	40	50	50	51
DSM	100	100	100	95	90	77	80	71
Philips	50	46	45	46	36	45	38	35
Shell	42	42	27	33	44	36	37	63
Unilever	25	18	21	21	24	22	14	12

Source: Rensman, 2004. R&D-personnel: CPB company database, April 2004. R&D-expenditures: Cornet and Rensman (2001), Table 2.5, p.20, with update for 2002. If no data were available for the years under consideration, the nearest years are chosen.

of domestic R&D activity has fallen. The expansion of R&D activities abroad is in line with the stronger economic growth in other countries, such as China, than in the Netherlands.

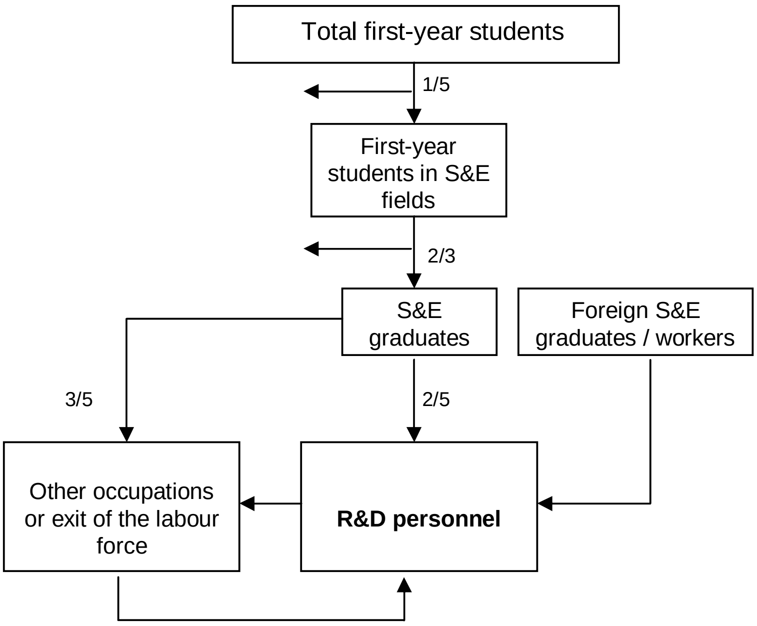
5 The supply of S&E (and R&D) personnel

Since 1975 the number of graduates from higher education has more than doubled. The share of S&E graduates from university decreased from 28 % in 1975 to 20 % in 2002. In higher vocational education this share decreased from 22 % in 1975 to 20 % in 2002. The lower shares of S&E graduates mainly originate from a composition effect due to the increased enrolment of female students. The developments in the supply of S&E graduates sharply contrast with those of graduates in economic studies. Their shares rose by 8 %-points for university graduates and 25 %-points for graduates from higher vocational education (HBO).
In 2002 one out of three S&E graduates worked in core R&D. This share has decreased by 8 %-points since 1993. R&D is primarily done by young workers; 43 % of S&E university graduates between 25-29 years works in R&D against 27 % of 45-55 years. Internationalisation is important in public and private R&D and seems to be increasing. the share of foreign workers in public and private R&D is substantial and seems to be increasing. On the other hand, the share of Dutch graduates working abroad is increasing, especially S&T graduates interested in scientific jobs. Compared to other countries the Dutch shares on inflow and outflow seem relatively low.

5.1 The supply chain from enrolment to working in R&D

In this chapter, we look at the supply of possible R&D workers, namely students graduating with an S&E degree. However, the number of graduates is not the only determinant of the stock of R&D personnel. S&E graduates have other choices in the labour market and also there is an inflow of foreign S&E workers, be it graduates or experienced staff. Also note that people who have originally chosen to work in other occupations, could still be persuaded (by interesting job offers or otherwise) into an R&D occupation although this will become more difficult the longer a worker has not done R&D work. These flows are summarised in the figure below, which pictures the flows that determine the effective supply of scientists and engineers. The inflow of first-year students in S&E fields and the drop-out rate out of these fields determines the actual stock of S&E graduates. The entry and exit of S&E graduates into R&D occupations and the inflow of foreign S&E graduates determine the actual stock of R&D personnel available in the economy. The figures attached to the channels will be explained in this chapter.

Figure 5.1 Flows in the supply chain of scientists and engineers



Key: The easiest way to interpret this flow chart, is by taking an example with real numbers. For instance, if (for some reason, be it policy or by other causes) the number of first year students would rise by 500, then the number of first year students in S&E would increase by 100 people; 67 would graduate and subsequently 27 would start a job in R&D. After a while, some of them leave as well to other occupations (about 2 % per year for university students). Looking at it from the other way: if the goal is to increase R&D personnel by 100 people, this would imply 250 S&E graduates, which would imply 375 new first year S&E's. If this has to come from an straight increase (rather than a change in the S&E preference of first year students) in first year students, you'd need 1875 more first year students.

5.2 Enrolment of first-year S&E students

As can be seen in Figure 5.1, a crucial factor in the supply of R&D personnel is the enrolment of new students into S&E fields in higher education. Enrolment trends indicate whether the interest of students for science and engineering careers are changing. Table 5.1 presents the growth rates in the number of first-year male students per field of study over the 1975-2002 period. Three observations are striking. First of all, the total number of first-year students (university and higher vocational education (HBO)) has doubled since 1975. Secondly, the absolute number of students in science and engineering have increased over the last decades. Although enrolment in science fields at university decreased by 3 %, engineering enrolment increased by 71 %. In higher vocational education the growth in engineering enrolment was slower (39 %). The third striking feature of Table 5.1 is the explosive growth of enrolment in economic studies.

Table 5.1 Growth rates in the number of first-year students (male and female), 1975-2002

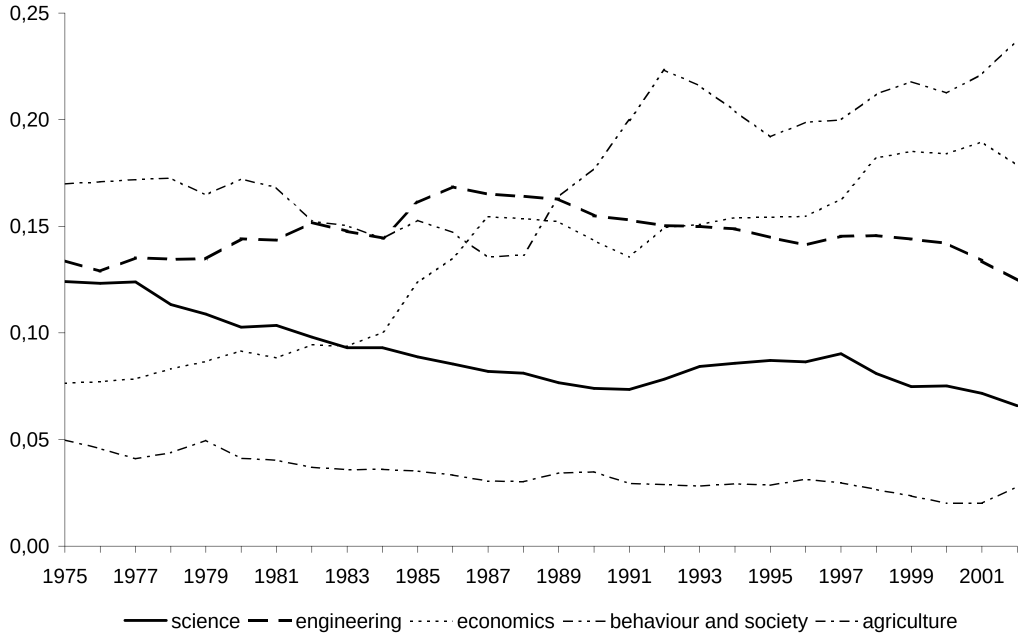
	Number of first years in 1975	Absolute growth in %	Growth of the share in %-points	Number of first years in 2002
University				
All students	19,502	+ 84		35,810
Science	2,421	– 3	– 6	2,360
Engineering	2,610	+ 71	– 1	4,470
Economics	1,493	+ 329	+ 10	6,400
HBO				
All students	32,809	+ 145		80,280
Engineering	9,926	+ 39	– 13	13,810
Economics	1,950	+ 1.312	+ 28	27,540

Source: CBS, 1992, 1994, Statline

However, given the large increase in the total number of students, absolute growth is not the whole story. We also look at the shares of the respective fields of study. The share indicates whether new students have different choice patterns than students from previous years. If we look at science and engineers there is a decrease in the share for university enrolment and a larger decrease for HBO students. This suggests a shift of interest of first-year students away from S&E fields towards, among others, economics.

Although not shown in the table above, the underlying figures for university students also show an increase in the share of behavioural studies. Relatively, languages studies have lost popularity. The shares for higher vocational education increased for health related subjects, at the expense of the social and behavioural studies. The evolution of the shares of first-year students can be seen in Figure 5.2 and Figure 5.3. If we look at the university students (Figure 5.2), the percentage of students choosing for science fields has decreased over the whole period. While, in 1975, 13 % of students enrolled in science, this is 7 % today. The enrolment share of engineering was quite stable, 14 % in 1975 and 13 % in 2002. In total, currently about one fifth of the first year students, both in university and HBO, enrol in an S&E field (this is the first arrow in the above figure). In contrast to S&E fields, social sciences have become increasingly popular in the last 25 years. The share of students enrolling in economics increased from 8 % in 1975 to 18 % in 2002.

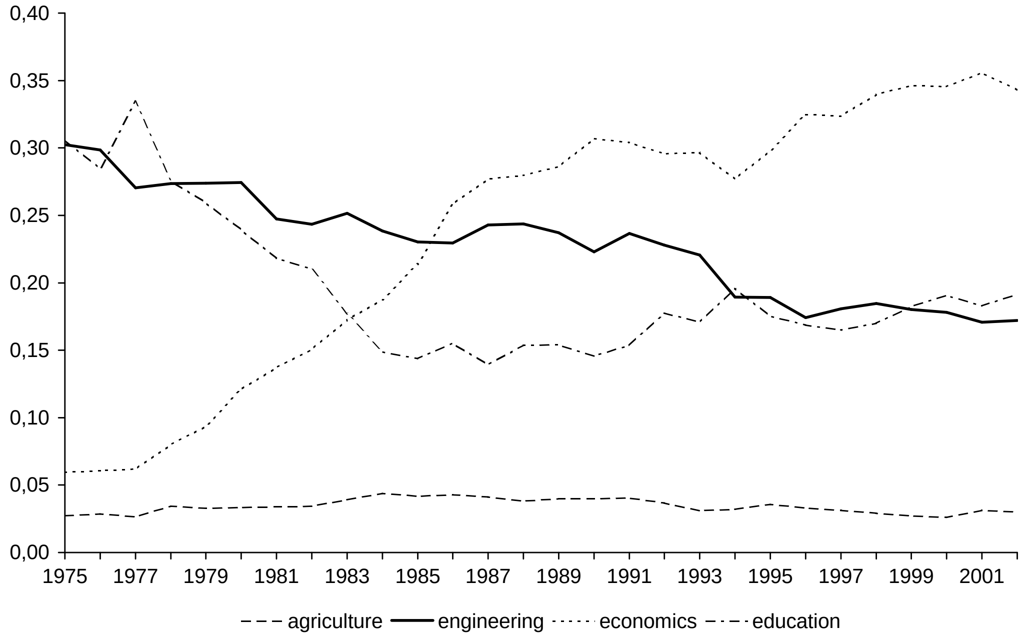
Figure 5.2 Shares per degree category of first-year students (male and female) at university



Source: CBS (1992, 1994) and CBS Statline.

In higher vocational education (Figure 5.3), the total S&E share has decreased by 13 %-points. In contrast, the economic cluster has experienced an explosive increase in enrolments from 6 % in 1975 to 34 % in 2002.

Figure 5.3 Shares per degree category of first-year students (male and female) in HBO



Source: No one consistent set of data exists. Therefore the figure is based on several sources, which contain similar, but not entirely comparable data. The years 1975 - 1991 are based on CBS (1992, 1994), 1992-1993 on CRIHO/CWI data and 1994-2002 on CBS Statline.

5.3 The supply of S&E graduates

The next step in the supply chain of Figure 5.1 is the number of first year students that actually graduate. The graduate outflow pattern is not identical to the student inflow pattern, and especially differs for HBO students. At this level the change in the share of S&E graduates is much smaller.

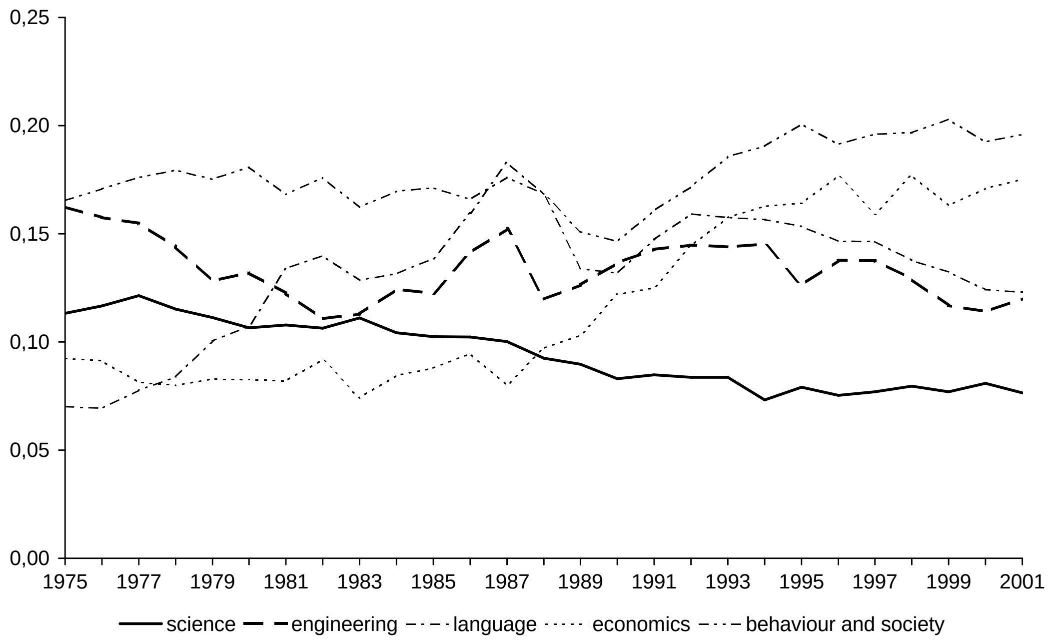
Table 5.2 Growth rates in the number of graduates (male and female), 1975-2002

	Number of graduates in 1975	Absolute growth in %	Growth of the share in %-points	Number of graduates in 2002[a]
University				
All students	9,979	+ 117		21,690
Science	1,130	+ 47	– 4	1,660
Engineering	1,621	+ 60	– 4	2,600
Economics	921	+ 313	+ 8	3,800
HBO				
All students	22,705	+ 109		47,480
Engineering	4,900	+ 94	– 2	9,530
Economics	1,700	+ 814	+ 25	15,530

[a] For university the figures are for 2001, since they refer to the pre-bachelor/master ‘doctoraal’ exams.
Source: CBS, 1992, 1994, Statline

Figure 5.4 and Figure 5.5 show the share of S&E graduates at both levels of higher education since 1975. At the university level we observe that the S&E shares decrease. The share of science graduates drops from 11 % in 1975 to 8 % in 2001 and the share of engineering students drops from 16 % in 1975 to 12 % in 2001. These changes mainly originate from the strong increase in enrolment of female students. For female students the share of S&E graduates is much smaller. Hence, an increase in enrolment of female students decreases the share of S&E students of the total student population. Changes are much smaller if we consider male and female graduates separately. The total share of male S&E graduates has dropped from 32 % in 1975 to 30 % in 2001. For female S&E graduates this share remained stable at 10 %, within which there was a shift from science to engineering. Hence, the drop in the total share of S&E graduates mainly originates from a change in the composition of the student population and not from a change in educational decisions. Judging from who graduates in what field, students do not seem to loose interest in S&E.

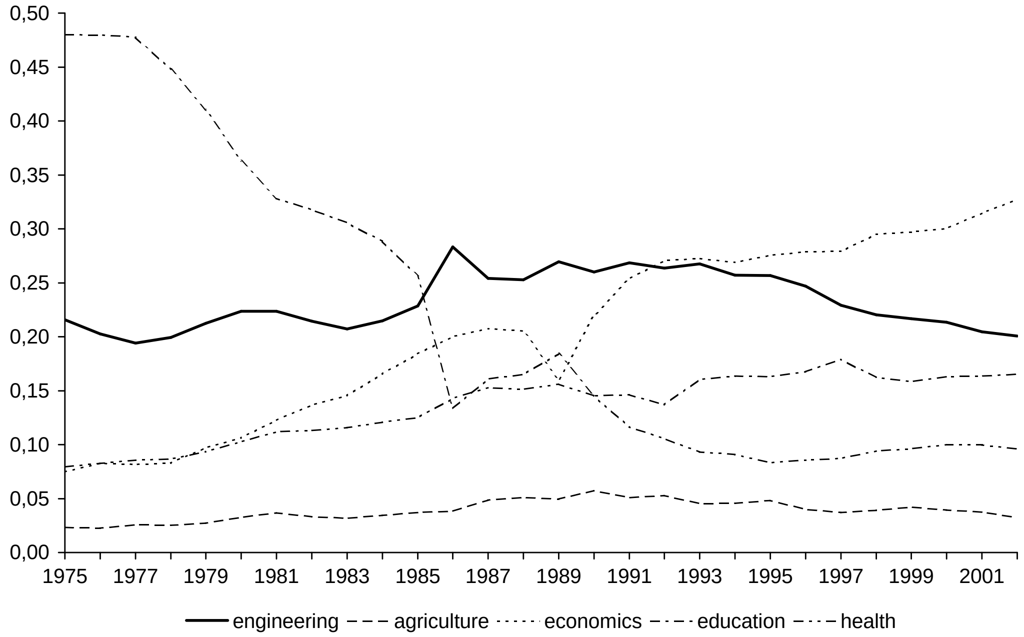
Figure 5.4 Shares per degree category of graduates (male and female) at university



Source: CBS, 1992, 1994, Statline.

At the level of HBO (Figure 5.5), we see the share of engineering graduates decreased from 22 % in 1975 to 20 % in 2002. Again, we see a composition effect: male S&E graduates' share increased from 35 % to 38 %, and female S&E graduates' share decreased from 7 % to 6 %. Hence the main reason why the total share decreased by 2 %-points is the larger growth of the total number of women over the growth of the number of men.

Figure 5.5 Shares per degree category of graduates (male and female) in higher vocational education



Source: CBS, 1992, 1994, Statline

Above we analysed movements in student numbers in about the last 25 years. If we take a shorter period of time, say the last ten years, the picture changes slightly although not dramatically. For HBO the last ten years show a decline in the engineering share, 6 %-points (rather then 2 %-points in the last 25 years). Whereas the male share actually increased over the last 25 years, it shows a decline if we look at the last ten years. For science fields at university level the picture looks different. The total decrease in share was 4 %-points over the last 25 years, but over the last ten years this was only 1 %-point (overall, about the same for men and women). Engineering at university level became 4 %-points less popular over the last 25 years, and 2 %-points over the last ten years. For males and females separately however, the decrease in share was 2 %-points or 0 %-points respectively, 2 to 3 %-points worse then over the 25 year period.

For the second arrow in Figure 5.1, we need to compare the numbers for outflow to those for inflow, albeit with a delay (namely, of the duration of the course of study). A rough comparison gives us a figure of about two thirds of the first year students who end up graduating.[17] This goes for both HBO and university S&E students.

Changes within S&E fields of study

The figures of total in- and outflows above are at a rather aggregate level. Now we take a closer look at the movement within the S&E field. Particularly, since an often heard perception is that

[17] This is consistent with the figures in OCW (2004).

students divert away from the ‘hard’ sciences towards the ‘soft’ sciences. The figures show that indeed some ‘hard’ sciences loose more students than other sciences, especially chemistry, but this does not apply to all ‘hard sciences’. The total number of university graduates in engineering declined from 3.430 in 1992/’93 (14 % of the total student population) to 2.600 in 2001/’02 (12 % of the total student population at that time). Table 5.3 summarises the change of the shares out of the total number of engineering graduates or science graduates, in the last decade. Note that, given a decreasing total number, a stable share implies a smaller number of graduates in 2001/’02 than in 1992/’93. For instance, notice in the table that the number of technical mathematicians went from 80 to 50, but that the share out of all engineers was stable. This means that students’ choice patterns didn’t change. On the other hand, the number of students in architecture increased from 280 to 480, an increase of a mere 70 %. In share terms, the 280 students were 8 % of the total population of engineering graduates in 1992/’93, and the 480 now are 18 %. The increase in share is therefore 10 %-points.

Table 5.3 Change of relative preference within university graduates S&E, 1992-2001

	Number of graduates in 1992	Number of graduates 2001	Change in share in %-points
Number of graduates, all fields	23,690	21,690	
of whom Engineering	3,430	2,600	
of whom Technical mathematics	80	50	0
Technical informatics	360	160	– 4
Civil engineering	170	290	6
Architecture	280	480	10
Mechanical engineering	560	300	– 5
Electrical engineering	480	190	– 7
Technical chemistry	380	200	– 3
Technical physics	260	200	0
Aviation- aerospace technology	110	100	1
Industrial design	150	130	1
Maritime engineering	20	30	1
Geodesy	20	10	0
Mining engineering	50	40	0
Technical business administer.	390	240	– 2
Engineering, other	110	180	4
of whom Sciences, all	1,980	1,660	
of whom Mathematics	110	110	1
Information science	360	300	0
Physics	230	210	1
Chemistry	440	200	– 10
Pharmaceutics	170	290	9
Biology	450	350	– 2
Physical geography	150	140	1
Environmental science	80	60	0

Source: CBS Statline

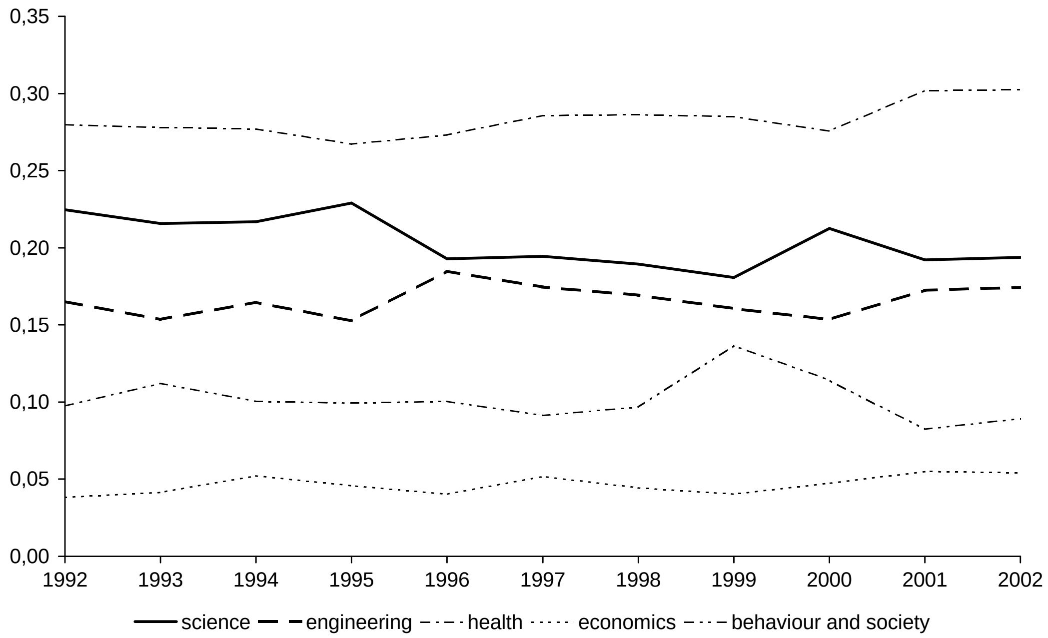
The bottom part of the table summarises the shares within science. The total number of science graduates was 1.980 in 1992/'93, and 1.640 in 2001/'02, which was in both cases 8 % of the student population. Especially in science, the shares are relatively stable, apart from a shift away from chemistry to pharmaceutics. The 'hard fields' in which one would have expected a decline (mathematics and physics) are not subject to large changes. In engineering, the 'winners' are the construction related fields (civil engineering and architecture), at the expense of electrical and mechanical engineering.

We constructed a similar table for higher vocational education. The picture there is comparable. The total number of HBO graduates in engineering was relatively stable at about 9.500 students. Construction related fields became more popular, as did information science. The share of technical physics declined by a small 1 %-point, which seems minor but it signifies a decline in the number of students of 40 % (from 180 in 1992 to 110 in 2002). One change stands out particularly: electrical engineering declined in share from about 20 % to about 10 %.

5.3.1 PhD's

The in- and outflow figures above include university and HBO students, but not students with an advanced degree. For the last decade, the total number of PhD's increased somewhat , from about 2.360 in 1992 to nearly 2.600 in 2002. As can be seen in Figure 5.6, the relative preferences of students was fairly stable as well. The already high share of medical PhD's increased slightly, as did the remarkably small share of economics students obtaining a

Figure 5.6 Shares per degree category of PhD graduates (male and female)



Source: CBS, 1992, 1994, Statline

doctorate. As for S&E courses, we see a decline in science, but a slight increase in engineering. The combined share of S&E PhD's fell from 39 % of the total number of PhD's in 1992, to 37 % in 2002.

It should be noted that the PhD's in figure 6.6 include Dutch and foreign PhD's. Although the numbers of PhD's are not decreasing markedly, the number of *Dutch* PhD's is declining. In Research voor Beleid (2005) figures are collected from various sources on the internationalisation of higher education. Two things become clear. First, about 20 % of the scientific staff at Dutch universities was foreign in 2004. Particularly the technical universities (Delft, Eindhoven and Twente) have a large percentage of foreigners (32 %), compared to about 13 % in other fields (except for agriculture, with 16 %). Secondly, the majority of foreigners at universities are concentrated in PhD programmes, and to a lesser extent in post-doc positions. At the technical universities, about half of the PhD's are foreign, in Eindhoven even 75 %. In the early '90's the share of foreigners at technical universities remained below 10 %[18]. Hence, these figures indicate that the share of foreigners has been increasing over the last 10 to 15 years.

5.4 Entry and exit in R&D occupations

Entry

The supply of scientists and engineers depends crucially on how many S&E graduates choose a career in science and engineering. The report 'Study and Work 2000' conducted by SEO/Elsevier (2002) collected data on the job occupations of higher education graduates who entered the labour market approximately two years before. Table 5.4 shows the distribution of university and HBO S&E graduates on the labour market by occupation.

The proportion of university S&E graduates working in (private) R&D[19] after their study remains generally below or around 25 %. Engineering graduates work generally more in R&D (except for civil engineering) than science graduates. Among science graduates, 24 % of informatics students move on to work in private R&D after their studies, while only 7 % of chemistry students do so. Instead, graduates in exact sciences mark a clear preference for PhD programs. Recent graduates in mathematics are the most spread among occupations. Among HBO students, more than 50 % of the graduates in chemistry hold an R&D-occupation after their study. The outflow into R&D is less for other fields of study.

[18] Intermediair, 9 January 2003.

[19] Persons classified in the 'research and R&D' sector have responded that they occupy one of the following functions: 1) post- docs, 2) scientific researcher, 3) market or marketing researcher, 4) leader/ employee in technical (industrial) R&D, 5) leader/ employee in environmental R&D, 6) leader/employee in process and production development, 7) leader/employee in a laboratory, 8) chemical or physical analyst, 9) other R&D functions.

Table 5.4 **Distribution of recent S&E university graduates among occupations, in percentages, 2000 (graduation between 1.5 and 2.5 years ago)**

Field of study	Occupation Economics	Education	Computing	Engineering	PhDs	R&D
University						
Mathematics	5	29	14	10	14	14
Physics	0	8	12	2	52	18
Chemistry	0	28	11	7	43	7
Informatics	0	0	54	4	10	24
Biology	3	4	5	1	46	19
Mechanical engineering	2	2	8	40	8	26
Electrical engineering	0	0	27	27	7	27
Chemical engineering	1	2	4	25	17	26
Civil engineering	3	0	4	49	1	11
Higher vocational education						
Chemical laboratory education	0	0	7	14	-	52
Electrical engineering	3	3	28	44	-	11
Civil engineering	0	0	0	75	-	0
Chemical engineering	0	0	7	22	-	53
Computing	3	0	67	7	-	7

Source: SEO/Elsevier. Own computations for university graduates – N (univ)=3.272. Reproduced from SEO/Elsevier (2000) for HBO graduates.

The figures in Table 5.4 raise the question what happens with S&E graduates after their PhD. This question can not be answered with these data. However, data from the Dutch Labour Market survey (*Enquête Beroepsbevolking*) include the whole sample of S&E graduates ranging over all age groups. Hence, these data can give a more comprehensive picture of the occupational decisions of S&E graduates.

We focus on the sub sample of S&E graduates aged between 25 and 55 years-old with a higher education (university or higher vocational education). The definition of S&E fields in the Dutch Labour Market Survey includes the fields of science, engineering and agriculture (and transport for higher vocational education). Table 5.5 shows that, in 2002, 34 % of all university S&E graduates aged 25-55 are working in core R&D occupations.[20] This is almost 7 % less than in 1993, although there has been a small increase since 1997. The declining trend is also observed for HBO graduates. In 1993, 43.5 % of S&E HBO graduates were working in core R&D. In 2002, this share is of only 36 %. In general, however, HBO graduates tend to work more in core R&D than university graduates.

Decreasing trends in core R&D contrast with increasing trends into other R&D occupations including managerial positions.

[20] Core R&D occupations are defined as mathematical, physical, biological and engineering occupations at higher and academic levels. Other R&D occupations are defined as managing positions and other occupations at higher and academic levels.

Table 5.5	Percentage of S&E graduates (including PhDs) working in R&D		
	1993	1997	2002
University			
R&D core	41.7	32.2	34.4
R&D other (excluding core)	8.2	11.2	11.1
Higher vocational education			
R&D core	43.5	37.2	36.1
R&D other (excluding core)	5.8	7.0	6.6
	N=2,013	N=2,272	N=2,608

Source: EBB, 1993, 1997, 2002.

The Gini-Hirschman coefficients[21] presented in Table 5.6 give an indication of the distribution of the different graduates over occupations. A coefficient of 0 indicates that a field of education leads to only one type of occupation. A higher coefficient indicates that a given education yields to more occupations.

Table 5.6	Gini-Hirschman coefficients		
	1993	1997	2002
University			
S&E	0.89	0.92	0.92
Economics	0.86	0.86	0.88
Higher vocational education			
S&E	0.89	0.90	0.89
Economics	0.76	0.78	0.77

Source: EBB 1993, 1997, 2002, own computations.

Three observations emerge from Table 5.6. First, S&E graduates are generally more spread out over occupations than economic students. This is true for both university and HBO graduates, as indicated by a larger Gini-Hirschman coefficient for S&E graduates. Second, S&E university graduates work in a slightly larger range of occupations today than 10 years ago. This is indicated by an increase in the Gini-Hirschman coefficient for S&E university graduates from 0.89 in 1993 to 0.92 in 1997 and 2002. This trend is, however, not observed for HBO S&E graduates. Third, HBO students tend to be more concentrated in certain occupations than university students. This is expected since HBO is a vocational type of education.

[21] The Gini-Hirschman coefficient is calculated as follows: $GH_k=(1-\Sigma_i e_{ik}^2)(m/m-1)$ where e_{ik} is the share of occupation i in the education sector k, and m is the total number of occupations.

Exit

Table 5.7 provides a further breakdown of the last column of Table 5.5, namely it gives the distribution of S&E graduates over R&D occupations per age class using 2002 data from the Dutch Labour Market Survey.[22] About 43 % of the young S&E university graduates (between 25 and 29 years old) work in core R&D occupations; for HBO this figure is 37 %. We use this number in Figure 5.1, as an indication of the share of S&E graduates who move on to a job in R&D. Taken for HBO and university together, a rough estimate of two fifths of the students follow this path. Note that this figure includes students who have done a PhD in between their graduation and their occupation in R&D.

The figures in Table 5.7 are also useful to see how long graduates remain in R&D jobs. As we see, only 27 % of S&E university graduates aged 45-54 still work in R&D. There is clear evidence that, along their career, university graduates tend to leave core R&D occupations. HBO graduates in the age class 30-34 work more in R&D than younger or older graduates. Just as for university graduates, older S&E graduates generally leave core R&D and tend to work more in other R&D occupations. In general, the shift away from R&D occupations as age increases is larger for university than for HBO graduates. On average, 2 % of university graduates and 0.5 % of HBO graduates working in R&D occupations leave these professions each year.[23]

Additionally, a well-known phenomenon is that women working in R&D have a higher chance of exit than men. Empirical evidence on US data shows that women who have begun working in S&E jobs are more likely to leave these professions than men in comparable jobs, even when correcting for family characteristics (Preston, 1994). This high rate of exit of women seems to be related to a mismatch between women's preferences and S&E jobs requirements.

Table 5.7 Age distribution of S&E graduates (including PhDs) working in R&D (share in percentages)

	25-29	30-34	35-44	45-55
University				
R&D core	42.5	40.2	34.1	27.2
R&D other (excluding core)	9.4	6.9	11.3	14.6
Higher vocational education				
R&D core	36.5	37.9	37.6	32.6
R&D other (excluding core)	3.4	4.0	6.5	10.6

Source: EBB, 2002.

[22] Similar trends were observed using 1993 and 1997 data, which are therefore not reproduced here.

[23] This is the arrow from 'R&D personnel' to 'other occupations' in Figure 5.1. To compute the average yearly exit rate, we calculated the proportion of S&E graduates working in R&D in the group aged 27-47 and in the group 28-48. The difference gives the number of graduates that had left R&D occupations within one year. We calculated this rate for each year from 1994 to 2002 and averaged it over the period.

5.5 The international mobility of S&E graduates

Data on the mobility of S&E-graduates are hardly available. Internationally comparable data on migration of high-skilled people are only available at a highly aggregate level. However, we can sketch a rough picture using data on two categories of workers: science and technology (S&T) personnel and R&D-personnel.[24] The S&T labour force consists of managers, professionals and technicians working in the fields of physics, mathematics, life sciences, health and education. R&D-employees are a small sub group of these S&T-workers. Table 5.8 compares the share of foreign workers in the Netherlands with the EU-average.

Table 5.8 Share of foreign workers in 2000 (%)

	Labour force	Higher educated	S&T-personnel	Annual growth (%) foreigners S&T personnel, 1994-2000
EU-average	4.6	3.7	4.1	5.8
The Netherlands	3.9	3.4	4.0	7.3

Source: EC (2003), Table 4.4.5 and Figure 4.4.13.

S&T workers: low share foreigners, and relatively small flows

If we look at current shares, we observe that the total active S&T labour force in the Netherlands amounted to 2.5 million people in the public and private sector in 2000 (see also table 2.1).[25] About 16 % of these S&T workers were professionals working in physical, mathematical, engineering, health and life science occupations.[26]

In 2000, only 4 % of the S&T-workers were non-natives, of which more than 50% came from other EU-countries. This small share of non-natives is comparable to that of other EU-countries.[27] However, the current figure seems to be the result of a catch up with other EU countries. The annual growth in the number of non-native S&T employees on the Dutch labour market between 1994 and 2000 was with 7.3 % above the EU-15 average of 5.8 %. It is plausible that this is related with the relative strong economic growth in the Netherlands in this period.

If we look at flows instead, we notice that the in- and outflow of S&T workers is relatively small compared to the size of the Dutch S&T labour force. The inflow from other countries is

[24] The main sources of the data in this section are NOWT (2003), EC (2003), Bison (2002), EZ/ROA (2003), and the CPB Company Database of July 2003. See Rensman (2004) for an extended analysis.

[25] Includes both lower and higher educated people. In 2000, the size of the group higher educated S&T workers is 1,3 million, slightly more than half of the total S&T labour force (NOWT, 2003, Table 3.2, p.60).

[26] 'S&E-employees' as defined by EC (2003, p.437): aged 25-64, ISCO 21 and 22 (thus excluding teaching professionals, and excluding technicians). Note the definition includes health and life sciences (ISCO 22), and also both lower and higher educated people.

[27] See EC (2003), Table 4.4.5, p.236.

about 1 % of the total S&T labour force in 2000.[28] The outflow to other EU countries is of about the same magnitude as the inflow from these countries, resulting in very small net migration.
Data on the outflow to non-EU countries are not available, but probably smaller in size. Of the graduates of Dutch higher education who were working abroad in the period 1998-2002, only one fifth went to non-EU countries.

However, the S&T labour force is defined broadly, including non-beta, low educated workers. We now turn to a smaller sub group of S&T workers, namely R&D-workers.

R&D-personnel: high share foreigners, and relatively high mobility

In 2000, R&D-personnel constituted less than 4 % of the S&T labour force. About half of these R&D-workers are researchers, scientists and engineers in the public and private sector.[29] There is no systematic overview of the migration of R&D-workers and researchers from and to the Netherlands. The available sources suggest migration and mobility are important within this group of workers.

Inflow

- In 2004, about 20% of the scientific staff at Dutch universities was foreign (Research voor Beleid, 2005). This figure is higher (32 %) for the technical universities (Delft, Eindhoven and Twente). At the agricultural university Wageningen the share is 16 %. The foreigners are concentrated in PhD programmes and post-doc positions. At the technical universities, about half of the PhDs are foreign, in Eindhoven even 75 %. Looking at fields of science, it appears that natural sciences and engineering show relatively high shares of foreigners, 32 %, compared to about 13 % in other fields (except for agriculture, with 16 %).
- The share of higher educated foreign workers in R&D is relatively low in the Netherlands compared to Belgium, Sweden and the United Kingdom (EZ, ROA, 2003). The share of higher educated foreign workers from non-EU countries in Sweden and the United Kingdom is double the share of the Netherlands.

Systematic figures on changes in the share of foreign workers in R&D are not available. Individual multinational firms state that these shares are increasing (see box).

[28] Calculated as the inflows from EU and non-EU countries (14700+9747) divided by the S&T labour force (2449000).
[29] The Frascati manual presupposes that there is a correspondence between these researchers and high education (EC, 2003, p.436). Then the share of researchers in the total of higher educated S&T workers is estimated at about 3%.

Anecdotal evidence on the share of foreigners in multinationals in the Netherlands

- Philips expands its campus in Eindhoven. Its R&D activity is said not to be hampered by a limited R&D-budget, but rather by a shortage in available qualified personnel. In 2000, 40 % of the newly hired at Philips Research Netherlands were foreign. In 2002, this appears to be about 50%.[a]

- DSM expands its activities in China, but its R&D-units are still settled in Europe and the USA, because these units are embedded in a local network that is difficult to relocate. However, the availability of higher technical personnel is important. It is increasingly difficult to hire such personnel locally. In 2003, DSM Netherlands hired one third of its new research employees from abroad.[b]

- In 2003, 3.5% of Akzo Nobel's personnel in the Netherlands is foreign. Among personnel with a university degree, more than 7% came from other countries. More, this percentage is slightly increasing during the past few years.[c]

[a] Volkskrant, 24-02-2003, Hoog scoren op de hightech-markt, and Intermediair 45, p.13, respectively.
[b] Volkskrant 13-02-2003, China is hoop in bange dagen voor DSM.
[c] Akzo Social Annual Report 2003.

Outflow

- The share of Dutch university graduates working abroad has increased from 2.2 % in 1999 to 3.4 % in 2003. Within this group the share of graduates working in a research occupation increased from 33 % to 39 %. Approximately one quarter of this group works at an institute for higher education. The majority of these graduates working at a foreign institute of higher education are S&T graduates: 56 % in 1999 and 76 % in 2003 (RvB, 2005).
- The same pattern is found in EZ/ROA (2003). Higher educated Dutch graduates working abroad more often choose for research jobs. And this especially holds for S&T graduates.
- About 40 % of the Dutch scientists staffed at Dutch universities moved abroad in the past 5 years, but generally only temporarily (RvB, 2005).
- Compared to other European countries the share of Dutch graduates working abroad is low (EZ, ROA, 2003).

To summarise, the figures on inflow suggest that the share of foreign S&E workers in Dutch public and private R&D is substantial and seems to be increasing. The figures on outflow suggest that the share of Dutch graduates working abroad is increasing, especially S&T graduates interested in research jobs. However, compared to other countries the Dutch shares on inflow and outflow seem relatively low. The main conclusion is that internationalisation is important in public and private R&D and seems to be increasing.

6 Developments in the labour market for S&E graduates

High wages, high labour participation, low unemployment, long working weeks and high vacancy rates can be indicators of a tight labour market. In this chapter we find that the relative wages of S&E graduates compared to all other graduates declined, both at the university and the HBO level. Compared to economic graduates, whom we consider a more adequate control group, we find the same pattern. Especially the differences at the university level are remarkable: in 1996 S&E graduates earn on average 9 % less than economic graduates and this difference increased to 12 % in 2002. In the private sector the deterioration of the relative wage position of S&E graduates is stronger. S&E graduates working in private R&D earn 5 to 10 % more than S&E graduates in other jobs in the private sector. However, since 1996 this 'R&D premium' has decreased and the relative wage position of S&E graduates working in R&D has deteriorated even more than the wage position of other S&E graduates. The labour participation and employment of S&E graduates is on average lower than the participation and employment of other graduates. In addition, the labour market position of S&E graduates seems to be weakening since 1992. The number of hours worked and the vacancy rates also do not indicate a tight labour market for S&E graduates. We conclude that this range of indicators does not provide evidence for a tight labour market of S&E graduates. Instead, the data suggest that the labour market position of S&E graduates has been weakening since 1996.

In this chapter, we describe recent developments on the labour market for S&E graduates in the Netherlands. We start with a general description of how the labour market works (section 6.1). Next, we devote attention to the definition of a 'shortage'. The next sections show the results of the empirical analysis of changes in the Dutch labour market for S&E graduates. In section 6.2 we analyse differences in wages between S&E graduates and other graduates. In section 6.3 we look at differences in labour participation, employment and vacancies.

6.1 The labour market

Scarcity of S&E graduates on the labour market means that the demand for these graduates is large compared to supply. As in any market, the obvious measure for scarcity is the price, given that the market clears properly. On the demand side firms signal their need for scientists and engineers by their wage offers. Firms demanding more S&E workers have to offer higher wages so as to increase the supply of workers willing to work at their firm. The message to potential workers is clear: come to work for us, because we appreciate your labour more. However, as wages increase, demand will respond as well. Some firms will find raising wages too costly and reconsider their activities. Hence, the demand for S&E workers will decline when wages rise.

On the supply side, why would higher wages be an effective way to attract new S&E workers? There are three potential channels. The first channel is the supply of potential S&E workers in the labour market. Not all S&E students end up working in S&E professions. A higher wage level will give an incentive to switch between jobs and consider working (again) in an S&E profession. The second channel is that current S&E workers may decide to work more hours in their current occupation when it becomes financially more rewarding. The third channel is new entry of workers on the labour market. An increase in wages for scientists and engineers provides incentives for students to enrol in S&E fields because the relative benefits being an S&E worker compared to other jobs improves. Although clearly there is a delay, since it takes a few years to train a student into an S&E worker, the economic literature is conclusive on a positive relation between pay and enrolment.[30] [31]

The wages for S&E workers will adjust until demand and supply are equalised and the market for S&E workers clears. Indeed, shortages will disappear because prices increase if S&E workers become scarcer. This is efficient because scarce resources are allocated to activities where their marginal benefits are highest and low-productive activities will be stopped. At higher wages, firms demand less workers because they have become too costly and some workers will find it attractive to apply for a job as an S&E worker. This process of rising wages continues until supply and demand will be equilibrated.

The responsiveness of firms or workers to increasing wages is denoted by the elasticity of demand or supply. The elasticity measures the percentage-wise change in demand (or supply) with respect to a percentage-wise change in the wage. If supply is inelastic, that is, when workers do not react strongly to increasing wages, firms may demand more workers, but this only results in higher wages, not in more hires of S&E workers. Or, in other words, they need to increase wages a lot to attract new workers. If, on the other hand, supply is elastic, firms demanding more workers need to offer only slightly higher wages to attract a lot of potential employees.

As long as the market clears, there can be no ‘shortages’ in a literal sense because supply always equals demand if the market is in equilibrium. The only thing economists can say is that S&E workers have become *scarcer* if their wages are higher. If S&E workers are scarcer, their wages will go up. If there is ample supply, wages must come down. Although, markets can be out of equilibrium temporarily, economic forces will ensure convergence to equilibrium in the long run, unless there are all kinds of market distortions. See also the box in this section.
From this discussion follows that the definition of a ‘shortage’ is not well defined in an economic sense. Following RAND (2003), one could easily identify various types of ‘shortages’. In the short run, supply could indeed be too low to meet demand. But, market forces would normally eliminate these shortages in the long-run.

[30] See for instance the recent paper by Ryoo and Rosen (2004) about the labour market for engineers in the US. They show that the demand for engineers is very responsive to their price (i.e. wages), but also that supply is equally sensitive to future earnings. The observed time lag is about four years.

[31] Obviously, there are other elements which determine the relative attractiveness of a certain profession, like innate capacities, interests, training possibilities, social standing, non-wage benefits, etcetera. Often the latter are part of a package including an attractive wage.

Equilibrium in the labour market

The labour market follows, like any other economic good, the laws of supply and demand. The demand for labour is determined by the level of activity in the economy. Companies, operating on the product market, hire employees as long as they can contribute to the profits of the company. The supply of labour is determined by the number of persons participating in the labour force. The latter is defined as the sum of both the employed and unemployed.

The wage mechanism ensures that demand and supply converge over time (see Figure a). For instance, if demand for labour were to exceed current supply, there will be a (temporary) shortage of workers on the market. Due to this scarcity, firms will offer higher wages to fill their vacancies. So wages rise and, as a result, supplying labour becomes more attractive and more workers are willing to participate in the labour market in general, or in the segment where the shortage arises. The supply of labour increases until the point where supply meets demand. The wage at that point is called the market clearing wage level (w*). Inversely, when the supply of labour is larger than the demand, this surplus will lead to falling wages. Consequently, the supply of labour will decrease (and demand will increase) until the point where supply equals demand.

Two special cases:

1. Supply is inelastic. This is illustrated in Figure b. In this case, increasing the wage does not lead to an increase in supply. So the market does clear, but at an increased wage level, the level of employment remains the same.
2. Wages are rigid. In this case the wage level is bounded from above, due for instance to the institutional structure of the labour market (<u>w</u> in Figure a). This means that wages cannot increase enough to attract the supply that would be necessary. Hence, the market does not clear and there is a shortage (due to increased demand). In the reverse case, when wages are too high for the market to clear, there is unemployment.

Figure a The market for labour

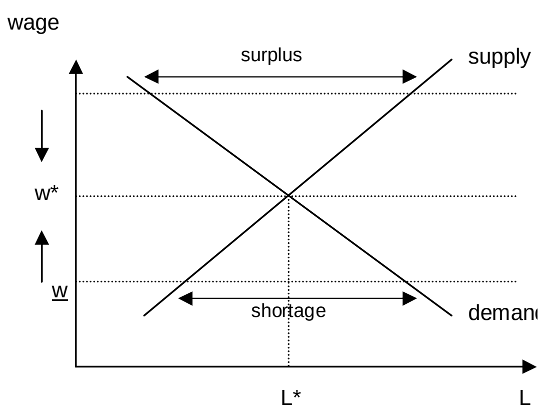
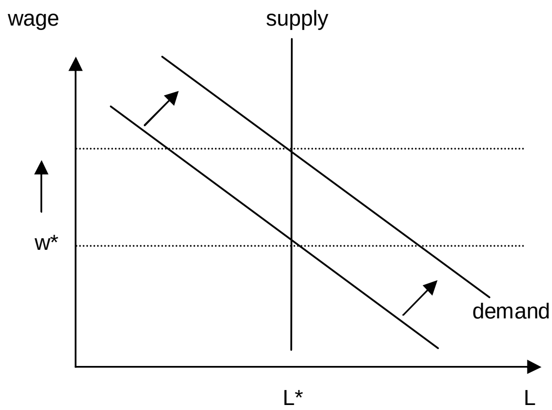


Figure b The market for labour with inelastic supply



Also, a ‘shortage’ can be perceived when there is a mismatch of actual supply compared to expected supply. Expectations may turn out to be wrong because they are based on levels from the recent past (e.g. declining number of graduates in S&E fields). Since the stock of workers on the labour market only adjusts slowly and quite predictably, it is not plausible that firms or workers are systematically mislead by prediction errors, as opposed to, for example, traders in the stock markets. ‘Shortages’ may also be perceived if levels are lower than what is deemed desirable in society (e.g. underinvestment in R&D). This has to do with a market failure (external effect) and could/should be restored by appropriate government intervention, see also later in this report. Also, the definition of 'shortage' may be confused by definition issues, e.g. what is considered part of supply. For instance, in the case of S&E's shortages are generally defined only in terms of domestic shortages and neglect international aspects. Based on all these considerations we will define shortage of S&E workers only in terms of scarcity.

In this analysis, we take a long-run perspective, in which we assume that price adjustments on the labour market ensure market clearing, firms and workers are well informed, and we take the foreign dimension of supply into account. These assumptions guarantee and imply that the wages are a correct and true measure for the scarcity of S&E workers. When necessary we will discuss the implications of relaxing our main assumptions.

An extensive empirical literature confirms the theoretical relation between wages, demand and supply. Katz and Autor (1999) document the role of supply and demand factors for understanding changes in the wage structure and overall earnings inequality. Ryoo and Roosen (2004) look particularly at the labour market for engineers. For a recent Dutch example of the relation between labour demand and supply, and wages, see table 6.1. During the economic boom of the late nineties, the demand for higher educated graduates increased strongly. After 2001 demand decreased. As can be seen in the table, the starting salaries of graduates of various types of technical and economic studies, seem responsive to these changes in demand.

Table 6.1 Starting wages by type of education, 1998-2003

	1998 Level[a]	1998 Index	1999	2000	2001	2002	2003
Electrical engineering	2040	100	109	122	122	121	118
Information science	2040	100	109	117	106	111	108
Chemical technology	1770	100	114	116	124	132	131
Technical business	2120	100	109	110	115	119	110
Technical information science	2030	100	111	125	131	109	110
Technical physics	1810	100	133	140	124	124	118
Technical mathematics	1830	100	109	120	117	125	114
Mechanical engineering	2030	100	109	113	118	121	123
Business	2210	100	101	108	111	115	114
Econometrics	2010	100	109	115	114	111	115
Economics	2090	100	108	111	113	119	116
Fiscal economics	2000	100	106	119	121	132	135

[a] Euros per month

Source: WO-monitor

The control group

In the next sections, we compare the job market situation for S&E graduates with those for other graduates on a number of indicators and particularly the wage level. Although the comparison with all other graduates provides useful insights, we also focus on a comparison with economic students. There are a couple of reasons why the comparison with economic graduates is useful.

First, in recent years there has been an increase in the supply of economic students on the labour market. This movement is interesting, since the supply of S&E graduates has gone down. Secondly, S&E and economic studies are possible substitutes for students. That is to say, students in S&E and economics by and large come from the same pool of high school graduates, namely those with science in their study profiles. Thirdly, the same principle applies in the labour market: economic and S&E graduates largely end up in the same jobs. Obviously, this is slightly one-sided: you won't find economists in a chemistry lab. However, you do find S&E graduates in all kinds of more economic occupations, like managerial positions. A particular example is the ICT bubble, when employers were hiring from the pool of both S&E's and economists.

Concerning size, the group of economic graduates is of about the same size as the group of S&E graduates. This can be seen in Table 2.2, which contains the outflows from higher education. The outflows also give an indication of the shares of these educational group in the labour force. Note that this is not the same as the number of people working in S&E occupations. This is due to the fact that many S&E workers work in non-S&E occupations.

6.2 Wage differentials

This section analyses the evolution of the wages of S&E graduates in comparison with all other types of graduates, and also separately with economic graduates. Based on data from the LSO, we compare recorded wage levels between the graduates of different fields of study. In the sample, S&E graduates are all people who indicated that their highest degree of education is higher vocational education (HBO), university or PhD in science, engineering or agriculture.

The basic procedure is as follows. We study each relevant sub-sample separately (e.g. all people with an HBO degree). For each group, we estimate a so-called Mincer wage equation in which the logarithm of the hourly wage is the dependent variable and the explanatory variables are age, age-squared, gender and type of education. In the regression, we always exclude one field of study, which thus serves as our reference group. In combination with the logarithmic specification, this allows us to interpret the coefficient as a wage differential in percentages. For instance, a found wage differential of 0.05 for the S&E field of study in the HBO group can be read as: HBO S&E graduates earn on average 5 % more than the reference group.

The top panel of Table 6.2 compares the average wages of S&E graduates with the wages of all other graduates. At the university level S&E graduates earn on average 2 to 3 % more than other graduates between 1979 and 1997. After 1997 the relative position of S&E graduates clearly deteriorated and in 2002 the wage level of S&E graduates is 2 % below the average level of all other university graduates. At the HBO level the relative position of S&E graduates improved strongly in the first halve of the eighties. In 1985 S&E graduates earned on average 10 % more than other HBO graduates. However, since 1985 this wage difference has declined steadily and in 2002 S&E graduates earned on average 5 % more than other HBO graduates. Hence, for both levels of higher education we find that the relative wage position of S&E graduates has been deteriorating since 1985.

Table 6.2 Estimation of wage differentials per type of education 1979-2002, compared to all other graduates

	1979	1985	1996	1997	2002
Compared to all other graduates					
University S&E graduates	0.02	0.03	0.03**	0.02*	– 0.02**
	(0.025)	(0.044)	(0.009)	(0.009)	(0.010)
	N=711	N=318	N=9,913	N=10,146	N=7,572
HBO S&E graduates	– 0.03**	0.10**	0.08**	0.06**	0.05**
	(0.014)	(0.017)	(0.006)	(0.006)	(0.006)
	N=1,737	N=882	N=23,644	N=23,422	N=17,535
Compared to economic graduates					
University S&E graduates	0.02	0.03	– 0.09**	– 0.09**	– 0.12**
	(0.027)	(0.047)	(0.010)	(0.010)	(0.010)
	N=711	N=318	N=9,913	N=10,146	N=7,572
HBO S&E graduates	– 0.06**	– 0.01	0.00	– 0.01	– 0.01*
	(0.017)	(0.024)	(0.007)	(0.007)	(0.007)
	N=1,737	N=882	N=23,644	N=23,422	N=17,535

An asterisk */** indicates significance at the 10% / 5% level. Standard errors are given in brackets.
Source: CBS, LSO 1979, 1985, 1996, 1997, 2002, own computations

The bottom panel compares the wages of S&E graduates with the wages of economic graduates, which we consider a more appropriate control group. At the university level we again find that the wage position of S&E graduates deteriorates but the changes are more dramatic. In 1979 and 1985 there is no significant difference in the hourly wages of S&E and economic graduates. In later years however, S&E graduates earn less per hour than their economic counterparts, up to 12% less in 2002. Hence, wages for economists have grown faster over the last 20 years than wages for scientists and engineers. For 1996 and later years we can distinguish between types of S&E education. For all types of S&E education, the relative wage position has deteriorated since 1996 (not shown in Table 6.2).

For HBO S&E graduates the picture is somewhat different. Since 1985, the wages of S&E graduates and economic graduates have been about equal. The pattern differs between types of S&E studies. HBO engineering students earned about 2 % more than economic graduates. There was no significant difference in later years. Graduates in science earned about 9 % and

12 % less than economic graduates in 1996 and 2002 respectively. Transport graduates earn 12 % more than economic graduates in 1996 and this increased to 18 % in 2002.

The samples used in Table 6.2 also includes graduates with a PhD-degree. To check for a possible bias of the results by this group we repeated all estimations for a sample excluding those with a PhD-degree. The results are quite similar. Since 1996, the relative wage position of S&E graduates at both levels of higher education has deteriorated against all other graduates. In addition, wages of S&E graduates strongly decline while compared to economic graduates at the university level and remain stable at the HBO level.

Moreover, the previous estimates focus on monthly wages and do not take changes in fringe benefits into account. From 1996 onwards, the Wage Structure Survey also contains data on the fringe benefits received by the different graduates. We constructed a new wage variable consisting of the structural and incidental elements and repeated all estimations of Table 6.2. The results are quite similar, although the drop in wages since 1996 of S&E graduates compared to economic graduates has been 1 %-point larger.

6.2.1 Wages of S&E graduates working in private R&D

Using again data from the LSO (Wage Structure Survey), we estimate the wage differentials of graduates working in the private sector. Estimation results are given in Table 6.3, column (1). In column (2), we also report coefficients for S&E graduates working in R&D occupations. R&D occupations are defined as the more technical occupations, i.e. in science and engineering. We estimated the wage differential for later years only, due to a lack of data on sectors and occupations in the Wage Structure Surveys of 1979 and 1985.

In Table 6.3, columns (1) present the estimates of the wage differential of graduates working in the private sector. In 1996 S&E graduates on average earned 4 % more at the university level and 8 % more at the HBO level than other graduates. In 2002 their wage position has deteriorated, at the university level they earn 4 % less than other graduates and at the HBO-level their wage advantage has decreased to 2 %. Hence, the findings are quite similar to the estimates in the top panel of Table 6.2, although the deterioration of the relative wage position of S&E graduates is stronger in the private sector.

Columns (2) in Table 6.3 and Table 6.4 give an insight in the premium an S&E worker gets from working in R&D. We compare the wages of S&E graduates working in private R&D and the wages of other graduates in the private sector. This results in what we call the total wage differential. I.e. university S&E graduates who ended up working in private R&D earn in 2002 1 % less than other university graduates working in the private sector. This total wage differential can be computed as the sum of the coefficient of S&E graduates and the coefficient of an interaction term. We can see that at both levels of higher education S&E graduates working in R&D earn more than other S&E graduates. The estimated R&D premium lies between 5 and 10 % and has been decreasing since 1996.

Table 6.3 Estimation of wage differential for S&E graduates working in private R&D, compared to all other graduates in the private sector

	1996		1997		2002	
	(1)	(2)	(1)	(2)	(1)	(2)
University						
S&E graduates	0.04**	0.00	0.03**	0.01	– 0.04**	– 0.07**
	(0.014)	(0.017)	(0.013)	(0.016)	(0.016)	(0.019)
R&D * S&E graduates		0.08**		0.05**		0.06**
		(0.022)		(0.021)		(0.025)
Sum: (total) wage differential		0.09**		0.06**		0.00
		(0.019)		(0.018)		(0.024)
	N=4,505	N=4,505	N=4,708	N=4,708	N=2,760	N=2,760
HBO						
S&E graduates	0.08**	0.04**	0.05**	0.01	0.02**	– 0.02
	(0.008)	(0.010)	(0.008)	(0.010)	(0.010)	(0.012)
R&D * S&E graduates		0.10**		0.09**		0.08**
		(0.013)		(0.013)		(0.015)
Sum: (total) wage differential		0.13**		0.10**		0.07**
		(0.012)		(0.011)		(0.013)
	N=11,233	N=11,233	N=11,226	N=11,226	N=6,095	N=6,095

An asterisk */** indicates significance at the 10% / 5% level. Standard errors are given in brackets.
Source: CBS, LSO 1996, 1997, 2002, own computations

Hence, the relative wage position of S&E graduates in R&D compared to all other graduates, as indicated by the total wage differential in Table 6.3, deteriorated even more than the wage position of other S&E graduates. Our analysis can not distinguish the factors that determine this R&D premium. Factors that may play a role are the match between education and job or selection effects if more 'high quality S&E-graduates' work in R&D. Table 6.4 shows the wage differences of S&E graduates in R&D compared to economic graduates.

The pattern of findings in Table 6.4 is quite similar to the findings in Table 6.2. The development of wages of S&E graduates at both levels of higher education lags behind wages of economic graduates. This holds both for S&E graduates working in R&D and in other jobs.

Table 6.4 Estimation of wage differential for S&E graduates working in private R&D, compared to economic graduates in the private sector

	1996		1997		2002	
	(1)	(2)	(1)	(2)	(1)	(2)
University						
S&E graduates	– 0.09**	– 0.13**	– 0.08**	– 0.11**	– 0.14**	– 0.16**
	(0.015)	(0.017)	(0.014)	(0.017)	(0.016)	(0.019)
R&D * S&E graduates		0.08**		0.05**		0.06**
		(0.021)		(0.020)		(0.024)
Sum: (total) wage differential		– 0.05**		– 0.06**		– 0.10**
		(0.019)		(0.018)		(0.021)
	N=4,505	N=4,505	N=4,708	N=4,708	N=2,760	N=2,760
HBO						
S&E graduates	0.00	– 0.05**	– 0.02**	– 0.06**	– 0.03**	– 0.07**
	(0.009)	(0.011)	(0.009)	(0.010)	(0.010)	(0.012)
R&D * S&E graduates		0.10**		0.09**		0.08**
		(0.013)		(0.013)		(0.015)
Sum: (total) wage differential		0.05**		0.03**		0.02
		(0.012)		(0.011)		(0.013)
	N=11,233	N=11,233	N=11,226	N=11,226	N=6,095	N=5,955

An asterisk */** indicates significance at the 10% / 5% level. Standard errors are given in brackets.
Source: CBS, LSO 1996, 1997, 2002, own computations

Robustness and selectivity of the results

The previous results show that the wage position of S&E graduates has deteriorated compared to other graduates. This indicates that there is no scarcity of S&E graduates in the Netherlands. It should be noted that this finding is based on a comparison of wage differentials over time. This makes other explanations less plausible. For instance, it has been suggested that S&E students are ‘nerds’ and ‘have more difficulty in negotiating high wages’. This unobserved factor may explain the difference in earnings between S&E graduates and other graduates at one point in time but not changes over time, since we may expect that hidden characteristics, like the ability to negotiate wages, do not change over time. Thus, it is not likely that selectivity will bias the finding that S&E graduates have become less scarce.

6.3 Labour market participation of S&E graduates

If the labour market for S&E graduates is tight we expect low unemployment, high labour participation, long working weeks and a high number of vacancies. In this section we contrast the labour participation of S&E graduates with all other graduates and with economic graduates using data from the Dutch Labour Market survey (EBB) in the years 1992, 1997 and 2002. An individual is defined as ‘participating’ if he or she indicates in the survey that they were either working or unemployed (at the time of the survey).

6.3.1 Chance of participating in the labour force

Do S&E graduates have more chance of dropping out of the labour force? We estimate the chance of participating (i.e. the chance of being employed or unemployed) versus the chance of non-participating. This gives an indication of the tendency of S&E graduates to exit the labour force. Probit estimates for the male and female sub samples (controlling for age) are given in Table 6.5. The top panel compares S&E graduates with all graduates, the bottom panel compares S&E graduates with economic graduates.

Most estimates in table 6.5 have a negative sign, which means that the labour participation of S&E graduates is lower than the participation of other graduates or economic graduates. Especially at the HBO level and for female graduates we find significant negative effects. The estimates also suggest that the participation of S&E graduates relative to other graduates has decreased since 1992. Hence, this indicator does not show that the labour market for S&E graduates has become tighter. In fact, the estimates show that the labour market for S&E graduates has become less tight.

Table 6.5 Chance of participating in the labour force (marginal effects)

	Male			Female		
	1992	1997	2002	1992	1997	2002
Compared to all graduates						
University S&E graduates	0.01	0.00	– 0.00	– 0.01	– 0.04	– 0.03
	(0.010)	(0.007)	(0.006)	(0.040)	(0.032)	(0.030)
	N=3.066	N=2.985	N=3.268	N=1.360	N=1.575	N=1.948
HBO S&E graduates	– 0.01*	– 0.03**	– 0.03**	– 0.06*	– 0.12**	– 0.12**
	(0.008)	(0.010)	(0.007)	(0.035)	(0.032)	(0.030)
	N=5,483	N=6,042	N=6,406	N=5,302	N=5,484	N=6,185
Compared to economic graduates						
University S&E graduates	0.00	– 0.00	– 0.01	– 0.03	– 0.10**	– 0.05
	(0.013)	(0.009)	(0.008)	(0.048)	(0.045)	(0.037)
	N=3.066	N=2.985	N=3.268	N=1.360	N=1.575	N=1.948
HBO S&E graduates	– 0.02	– 0.02	– 0.03**	– 0.01	– 0.11**	– 0.13**
	(0.011)	(0.012)	(0.011)	(0.036)	(0.034)	(0.033)
	N=5,483	N=6,042	N=6,406	N=5,302	N=5,484	N=6,185

An asterisk */** indicates significance at the 10% / 5% level. Standard errors are given in brackets.
Source: EBB, own computations

6.3.2 Chance of being employed

Next, we analyse the probability of employment for S&E graduates. Table 6.6 shows the results of a probit analysis on the probability of having a job. The top panel compares S&E graduates with all other graduates, the bottom panel compares S&E graduates with economic graduates.

Table 6.6	Probit estimates of the chance of being employed (marginal effects)					
	Male			Female		
	1992	1997	2002	1992	1997	2002
Compared to all other graduates						
University S&E graduates	0.01	– 0.02*	– 0.02**	0.04	– 0.05	– 0.03
	(0.013)	(0.012)	(0.011)	(0.042)	(0.036)	(0.030)
	N=3,066	N=2,985	N=3,268	N=1,360	N=1,575	N=1,948
HBO S&E graduates	– 0.02*	– 0.02**	– 0.03**	– 0.03	– 0.13**	– 0.13**
	(0.009)	(0.010)	(0.009)	(0.036)	(0.032)	(0.030)
	N=5,483	N=6,042	N=6,406	N=5,302	N=5,484	N=6,185
Compared to economic graduates						
University S&E graduates	0.002	– 0.03**	– 0.03**	0.01	– 0.09**	– 0.06*
	(0.015)	(0.015)	(0.013)	(0.051)	(0.046)	(0.039)
	N=3,066	N=2,985	N=3,268	N=1,360	N=1,575	N=1,948
HBO S&E graduates	– 0.02	– 0.02*	– 0.03**	0.004	– 0.13**	– 0.13**
	(0.012)	(0.013)	(0.011)	(0.038)	(0.035)	(0.033)
	N=5,483	N=6,042	N=6,406	N=5,302	N=5,484	N=6,185

An asterisk */** indicates significance at the 10% / 5% level. Standard errors are given in brackets.
Source: EBB, own computations

As in Table 6.5, we find that most estimates have a negative sign, which means that the probability of having a job is lower for S&E graduates than for other graduates or economic graduates. In addition, the probability of employment for S&E graduates has become more negative which means a deterioration of their labour market position. This holds for the comparison with all other graduates but especially for the comparison with economic graduates. As with the previous indicators, we find that the labour market of S&E graduates is becoming less tight when compared to other graduates.

6.3.3 Working time

If the demand for S&E workers is strong, they might work more hours per week, on average. In Table 6.7 we estimate the effect of different fields of study on the amount of hours worked controlling for age. We only look at the sample of employed workers. Again, the top panel compares S&E graduates with all other graduates, the bottom panel specifically looks at the difference between S&E graduates and economic graduates.

The picture in the top panel is mixed. Male S&E graduates at the university level work less hours than other graduates; at the HBO level S&E graduates, and especially female graduates, work more hours. Compared to economic graduates, whom we consider a more adequate control group, S&E graduates at the university level work less hours and there is no difference at the HBO level. As with the previous indicators, we do not find evidence for a tight labour market for S&E graduates.

Table 6.7 Working hours per week of S&E graduates

	Male 1992	Male 1997	Male 2002	Female 1992	Female 1997	Female 2002
Compared to all other graduates						
University graduates	– 1.11**	– 1.48**	– 1.26**	1.18	1.35	0.81
	(0.35)	(0.36)	(0.50)	(1.09)	(0.85)	(0.96)
	N=2,646	N=2,631	N=2,901	N=1,023	N=1,246	N=1,572
HBO graduates	0.67**	0.84**	1.02**	2.11**	1.43*	2.14**
	(0.22)	(0.24)	(0.32)	(0.84)	(0.79)	(0.88)
	N=4,636	N=4,942	N=5,438	N= 3,343	N=3,619	N=4,522
Compared to economic graduates						
University graduates	– 1.26**	– 1.57**	– 0.92**	– 1.25	– 0.93	– 1.96**
	(0.43)	(0.42)	(0.38)	(1.21)	(0.96)	(0.80)
	N=2,646	N=2,631	N=2,901	N=1,023	N=1,246	N=1,572
HBO graduates	0.12	0.14	0.04	– 0.24	– 0.45	– 0.98
	(0.27)	(0.27)	(0.25)	(0.89)	(0.84)	(0.72)
	N=4,636	N=4,942	N=5,438	N= 3,343	N=3,619	N=4,522

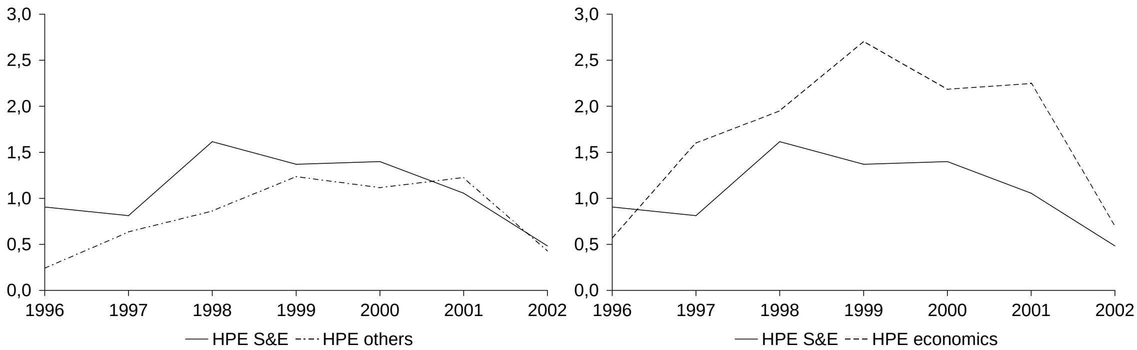
An asterisk */** indicates significance at the 10% / 5% level. Standard errors are given in brackets.

Source: EBB, own computations

6.3.4 Vacancies

The number of vacancies available for each type of graduates completes the analysis of the labour participation of S&E students. The vacancy index represents the number of (difficult to fill) job vacancies corrected for the total employment per sector of education. The index is computed using data from the CBS Vacancy survey over the years 1996-2002. Figure 6.1 and 6.2 show the evolution of the vacancy index for S&E graduates compared to all graduates and compared to economic graduates.

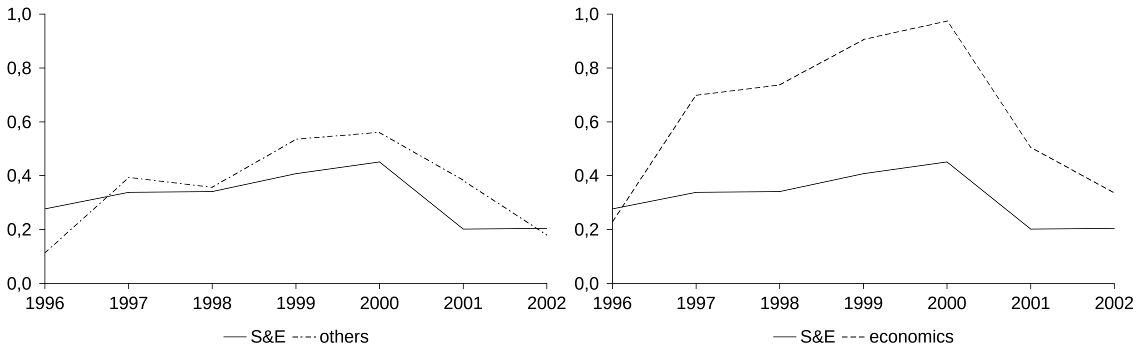
Figure 6.1 Vacancy index for HBO graduates, difficult to fill vacancies, 1996-2002



Source: CBS vacancy survey

Figure 6.1 and 6.2 show that the vacancy rates of S&E graduates are at about the same level as the vacancy rates of all other graduates. In addition, the vacancy rates of economic graduates are higher, both at the university level and at the HPE level. This is in line with our previous findings that there had been a larger demand for economic graduates than for S&E graduates over this period. The same pattern is found if we look at all vacancies. Hence, vacancy rates for S&E graduates do not suggest a tight labour market.

Figure 6.2 Vacancy index for university graduates, difficult to fill vacancies, 1996-2002



Source: CBS vacancy survey

7 Forecasts

Labour market forecasts indicate that the expected demand exceeds the expected supply for almost all types of higher education, including S&E graduates. This is driven by the ageing of the labour force. The predicted vacancy rate in S&E studies is lower than in some other disciplines. As a consequence, market forces may be stronger in attracting students and graduates to non-S&E types of education and jobs.

The previous sections dealt with statistical data, which are by definition concerning past development. However, also given the ambitions in the Deltaplan, it is useful to try and get in inside in future developments. What can we expect on the labour market for knowledge workers in the coming years?

The most recent forecasts for the labour market in the next years can be found in ROA (2003). Forecasts are made for specific occupations and types of education. The ROA forecasts are based on a confrontation of the expected number of school leavers with the expected change in demand (replacement and enlargement of workers). The outcome of this confrontation is translated in the so-called ITKP indicator (*Indicator toekomstige knelpunten in de personeelsvoorziening naar opleiding*). This indicator characterises the hiring problems of employers. A low score indicates large hiring problems, a high score indicates that the supply of workers is larger than demand. Table 7.1 shows the most recent forecasts. The second column shows the expected new demand of workers through an increase in activities or a replacement of older workers. The third column shows the expected number of new entrants to the labour market (including short term unemployed, as they are part of supply) and the fourth column shows the difference between demand and supply.

Table 7.1 Supply and demand 2003- 2008 per type of higher education

Type of education	(1) Demand	(2) Supply	(1) - (2)	Share of employment 2002	ITKP-indicator[a]	
Higher vocational education						
Science and engineering	61,200	49,400	11,800	– 5%	0.99	Large
Economics	62,000	81,200	– 19,200	+ 4%	1.05	Some
Education / social cultural	161,300	105,600	55,700	– 10 %	0.97	Large
Medical	43,300	23,000	20,300	– 16 %	0.92	Large
University						
Science and engineering	29,700	18,400	11,300	– 8%	0.92	Large
Economics	52,600	42,100	10,500	– 5%	0.93	Large
Languages / social cultural	48,400	29,600	18,800	– 11%	0.95	Large
Medical	13,900	12,600	1,300	– 1%	0.99	Large

[a] Indicator of future bottlenecks in staffing by education. An ITKP smaller than 1 indicates expected future hiring problems.
Source: ROA (2003), p. 36, 39, 61

The forecasts in Table 7.1 show that expected demand for science and engineering workers exceeds expected new supply of these graduates. This holds both for higher vocational and for university education. This unbalance of supply and demand is, with one exception, also predicted for all other types of education. Especially, in the education and medical sector at the higher vocational level, there are large gaps between the expected supply and demand.

The driving force behind these unbalances is the ageing of the work force. In most education types, 75 % of new demand originates from the replacement of older workers. The main conclusion from these forecasts is that expected demand exceeds expected supply for almost all types of higher education. The ageing of the labour force will lead to absolute shortages of workers everywhere.

In this sense, the figures in Table 7.1 are not very informative. No policy can solve absolute shortages. It is more informative to look at relative shortages because it is the relative supply on the labour market that determines relative wages and thereby influences enrolment decisions and choices of job type. The fifth column in Table 7.1 shows the differences between demand and supply as a share of total employment in 2002 in a particular type of higher education. These numbers could be labelled as the 'predicted vacancy rate'. The predicted vacancy rate in S&E studies is lower than in some other studies at both levels of higher education. As a consequence, we may expect that market forces are stronger in attracting students and graduates to non-S&E types of education.

Despite the fact that the absolute demand for S&E graduates exceeds the absolute supply, it is plausible that the relative demand for S&E graduates, and the relative demand for R&D workers, will fall. This could further undermine the wage prospects of S&E graduates. However, it remains difficult to draw firm conclusions from the figures in Table 7.1. The forecasts are based on a large number of assumptions. For instance, adjustments in wages, in activities of firms or in the hiring of employees are not taken into account. The same holds for drop-out rates, share of part time work etcetera, which could also be responsive to changes in the wage level. In addition, it should be noted that these forecasts apply to the whole range of activities done by S&E graduates. There are no separate forecasts for supply and demand for R&D activities. The previous sections showed that approximately one out of three S&E graduates works in core R&D, suggesting that there exists a large pool of S&E graduates not working in R&D. Moreover, R&D is typically done by young employees (Table 5.7). We might expect that the demand for R&D workers will be less affected by the need to replace workers that are retiring.

7.1 Student decisions in secondary education

As an indication of future flows, we can look at the choice of pupils who are currently in secondary school. In particular, we can check whether there are trends in the numbers of pupils who choose 'study profiles' that allow entry into S&E degrees in higher education. If pupils no longer enrol in these science study profiles, the inflow into S&E studies will dry up.

Table 7.2 shows the allocation of students over the so-called 'study profiles' in the two highest types of secondary education. These profiles were introduced in grade 4 of the school year 1999-2000. Students can choose out of four separate profiles: science & engineering (N&T), science & health (N&G), economics & society and culture & society. Moreover, they can combine the science profiles and the society profiles.

Table 7.2 Subject profile in secondary education, share of total student population by grade (%)

	Pre-university education (VWO)				Higher general secondary (HAVO)			
Grade 4	N&T	N&G	Combined	Total	N&T	N&G	Combined	Total
1999	13	17	20	50	14	14	2	30
2000	12	19	18	49	14	15	1	30
2001	12	20	18	50	12	16	1	29
2002	11	20	18	49	11	16	1	28
2003	11	20	19	50	11	17	1	29
Grade 5								
2000	16	24	6	46	14	13	0	27
2001	16	26	5	47	13	15	0	28
2002	15	28	4	47	11	16	1	28
2003	15	29	3	47	11	16	1	28
Grade 6								
2001	16	24	3	43				
2002	15	27	3	45				
2003	15	28	3	46				

Source: OCW (2004)

Table 7.2 shows that the share of students choosing for the 'exact profiles' is rather stable or slightly increasing (in pre-university education). Within this pool of 'exact students' there is a clear trend: the share of students opting for the N&T profile is decreasing and the share of students choosing for the N&G profile is increasing. Hence, health oriented subjects and probably also health oriented studies are becoming more attractive and engineering seems to be losing ground. This reallocation within secondary education can have consequences for the future supply of R&D workers. Is seems likely that the specialisation of the supply of future R&D workers will be more oriented towards health issues.

8 The S&E puzzle

How can we explain that employers experience hiring problems when all our labour market indicators suggest the opposite? The internationalisation of R&D activities may be a possible explanation. Wages for Dutch S&E workers may be determined in an international labour market for S&E graduates. If the international wage level is below the market clearing level in competing parts of the Dutch labour market, firms will have problems with hiring Dutch S&E graduates. Another explanation may be found in the aggregation level of the data. In most of the analysis we focus on the whole sample of higher educated S&T graduates. At a more disaggregated level the picture might be different. In some disciplines it might be difficult for employers to hire graduates. In other disciplines it might be difficult for graduates to find a job.

In the previous chapters we looked at a wide range of labour market indicators: vacancies, unemployment rates, wages, labour market participation and weekly working hours. The main finding from this empirical analysis is that we do not find evidence for a tight labour market of S&E graduates. Instead, the data suggest that the labour market position of S&E graduates has been weakening since 1996. This conclusion is based on a comparison of S&E graduates with all other graduates. If economic graduates are taken as control group, most indicators show that the labour market for economic graduates was tighter. In addition, approximately one out of three S&E graduates works in core R&D and this share has decreased in the last decade. Our results are in line with findings of a previous study by Groot and Plug (1999). Using data from OSA labour market surveys over the years 1985-1996, they rejected the evidence of a shortage of S&E graduates. They found that graduates in engineering fields (including lower and higher education) earned on average 10% less than non-engineering graduates. They also find that high educated non-engineering graduates have a higher probability of employment than high educated engineering graduates.

Changes in relative demand

Our findings are remarkable considering the general concern for shortages of S&E graduates in the last decade and the major divergence in supply side developments. Since 1975, the supply of university graduates in economics has increased by 218 % and the supply of HBO graduates in economics has increased by 717 %. The increase in S&E graduates in this period remained below 50 %. This suggests that there have been strong forces at work on the demand side of the labour market. Despite the large increase in relative supply of economic graduates we still find that the labour market for these graduates is tighter than for S&E graduates. This can only be explained by a major increase in demand for economic graduates. This strong demand for economic graduates may also probably have affected the supply of S&E graduates. Attractive jobs for economists might have led students to choose for economic studies in stead of S&E studies. This strong demand for economic graduates might also be part of the explanation for the low share of S&E-students. This picture of the labour market developments also has implications for policies which aim to increase the number of S&E graduates. The main implication is that policy interventions have to compete with strong market forces leading students to other alternatives. The experience of the last decades shows that these forces have led many students to choose for economic professions. In addition, the effects of these policies might only be temporary as they can reinforce market forces. For instance, if some policies attract more students in S&E studies this may increase the shortages of economic graduates. These market forces limit the opportunities for government interventions and raise questions about the effectiveness of policy interventions. This issue however, is not unique to government policies concerning S&E graduates. The fact that the labour market indicators do not provide evidence for shortages of S&E graduates poses a puzzle. How can we explain that employers experience hiring problems when all our labour market indicators suggest the opposite?

Internationalisation

A possible explanation may be found in the internationalisation of R&D activities and the R&D labour market. The market for S&E graduates becomes more and more international as a large share of R&D activity is done by multinational firms. This has major implications for demand and supply of S&E graduates in the Netherlands. On the one hand, Dutch firms have access to an international supply of S&E workers and this will put a downward pressure on wages. On the other hand, firms may relocate R&D activities to countries with the largest comparative advantage in doing R&D.

The analysis of demand and supply provides evidence that this process is happening. In recent years we observe an increase of foreign S&E graduates in Dutch universities and private R&D. At the same time the share of Dutch S&E graduates working in R&D has decreased by 8 %-points since 1993. Moreover, the share of Dutch graduates from higher education working abroad is increasing, especially S&T graduates interested in scientific jobs. This is in line with a growing internationalisation of the market for S&E graduates. As a result, wages for Dutch S&E graduates will remain at the international level for S&E graduates. If this level is below the market clearing level in competing parts of the Dutch labour market, firms will have problems with hiring Dutch S&E graduates. In that case, they will have to substitute domestic S&E workers with foreign S&E workers, even if this implicates higher costs and more uncertainty about the stability of the working relation.

The other side of this story is that firms will relocate their activities if the dependence on foreign workers becomes too large. The observation that Dutch multinationals do not expand R&D in the Netherlands but abroad seems in line with this. In an international market firms move their activities to countries with comparative advantages.

It seems clear that internationalisation is important in the market for R&D. In addition, the labour market for S&E graduates seems more international than the labour markets for other higher educated workers. Nevertheless, it is not clear if internationalisation is the major explanation of the S&E puzzle. For instance, can internationalisation really explain that since 1996 wages of S&E workers compared to all other graduates have fallen by 5 % at the university level and 3 % at the HBO level? Hence, it seems safe to conclude that internationalisation may be part of the solution of the S&E puzzle but we are not sure if this is the whole story.

The level of aggregation of the data

Another factor that may explain the divergence between the experiences of employers and the empirical findings is the level of aggregation of our data. In most of the analysis we focus on the whole sample of higher educated S&T graduates. At a more disaggregated level the picture might be different. In some disciplines it might be difficult for employers to hire graduates. In other disciplines it might be difficult for graduates to find a job. Some empirical findings are in line with this explanation. The analysis of wage differentials shows that at the higher vocational level there is a large difference in the rewards of science graduates and transport graduates. In addition, since 1991 the enrolment shares of several disciplines has changed substantially.

If this explanation is important, than the main issue would be to improve on the match between the supply and demand of S&E graduates. This differs from the current policy targets aimed at increasing the number of S&E graduates by 15 %.

It is also questionable whether government policies can be effective in improving the match between supply and demand. It is well known that changes in specific labour markets are difficult to predict. Market signals are expected to be superior to ‘manpower planning’ by the government. Policies that focus on the design of the curriculum may be more successful. A broader curriculum could increase the number of candidates for specific jobs. The benefits of these policies should be weighted against the costs in terms of the loss of specialisation.

9 Policies to foster R&D

The choice between supply side and demand side policies depends on the degree of government failure in stimulating R&D activity. Demand side policies are directly targeted at increasing R&D activity whereas supply side policies generally are not. Supply side subsidies will leak away if S&E students will not graduates or will not enter R&D jobs. As a result of the internationalisation of R&D production domestic S&E workers have to compete with a growing influx of foreign S&E workers. This makes it less attractive to enrol in S&E studies which undermines the effectives of supply side policies.

An increase of R&D activities seems desirable given the evidence on spillover effects of R&D production. Currently the government uses a variety of programs which may stimulate R&D such as, tax credits for R&D personnel (WBSO) that raise the demand for S&E graduates, education subsidies to increase the supply of S&E graduates and recently the ‘Delta plan beta/technology’ which includes supply and demand policies (see also section 2.2.1). The question is which measures are most effective in promoting investments in R&D. Is it more effective to stimulate the supply of S&E students or the demand for R&D?

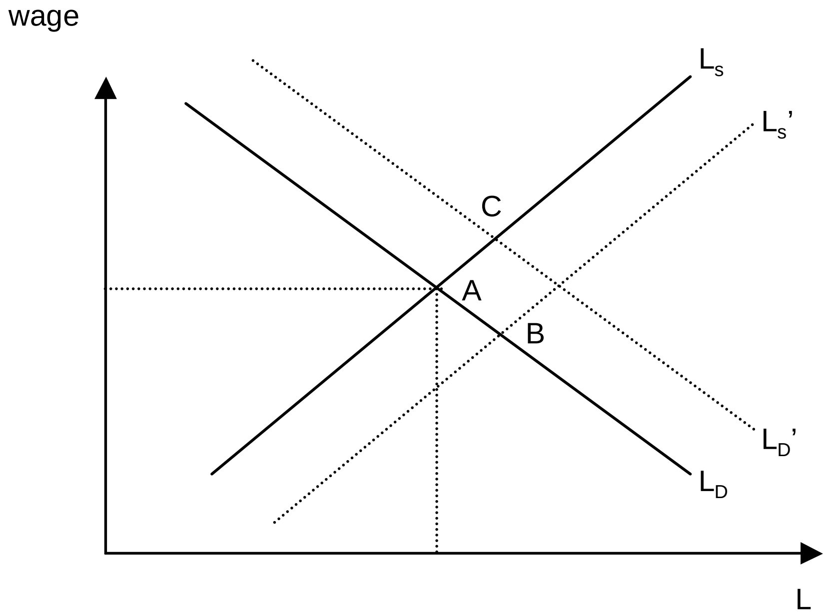
This section attempts to shed light on this question by analysing the consequences of demand side (which are aimed at the employers side of the market) and supply side policies (which are aimed at the employee side, i.e. the graduate). First, we analyse on a more abstract and theoretical level how subsidies on the demand and supply of R&D activities will affect the equilibrium level of R&D where the interaction of demand and supply is explicitly taken into account. As we shall see, ignoring the interaction between demand and supply may lead to misguided policy advice. Second, the analysis of various policies should not only take into account direct market responses but also the indirect (or unintended) effects. Some policies may feature little additionality and result in more substitution and crowding out effects than others. Hence, government failure is potentially important in many policy measures, and policies to foster R&D are no exception to the rule. Third, we pay attention to the consequences of the globalisation of R&D production for the choice between supply and demand policies.

9.1 Stimulating supply or demand?

In order to evaluate the effectiveness of R&D promoting subsidies, it is important to know how much more R&D will be generated. That is, whether policies will have sufficient additionality. The total effect of R&D policies depends on the interaction between the demand and supply sides of the market.

To illustrate this point, we consider a simple tax incidence model of the market for R&D personnel.[32] Assume that the supply L_s of R&D workers is increasing in the net incomes W_s of R&D workers: $L_s(W_s)$, with $L_s' > 0$. Policies that promote the supply of S&E workers – such as bonuses for S&E students – increase net incomes of S&E workers. Assume that net incomes are given by market wages W plus government subsidies ($S_{s,}$ as a percentage of the net-wage) to promote the supply of R&D workers: $W_s = W(1 + S_s)$. Similarly denote the demand for R&D workers L^d which is a decreasing function of producer wages W_d: $L_d(W_d)$, with $L_d' < 0$. Demand for R&D workers may be subsidised at rate S_d. As such we can write $W_d = W(1 – S_d)$. The equilibrium in the market for R&D workers is found where demand equals supply: $L = L_d(W(1 - S_d)) = L_s(W(1 + S_s))$. Figure 9.1 illustrates.

Figure 9.1 The labour market for R&D workers



Key: Equilibrium in the market for R&D workers is found at point A where the demand curve L_d and supply curve L_s intersect. An increase in subsidies on the supply of R&D workers shifts the supply curve out from L_s to L_s' and the new market equilibrium is found at B where wages are lower and total R&D activity is larger. An increase in subsidies on the demand for R&D workers shifts the demand curve from L_d to L_d' and the new equilibrium is found at C where wages will be higher as well as R&D activity.

What happens with the equilibrium level of R&D activity if, starting from an initial situation, we increase the demand or supply side subsidy (S_d or S_s) with one percentage point? If we assume for the moment that the market for R&D personnel is perfectly competitive and both employers and workers are price-takers, then we can find the following expressions for the percentage change in the equilibrium level of R&D employment $l \equiv dL/L$ and wages $w \equiv dW/W$ in response to a percentage change in the subsidies $s_d \equiv dS_d/(1 - S_{d},)$ and $s_s \equiv dS_s/(1 + S_s)$:

[32] See also Fullerton and Metcalf (2004) for a general discussion on tax incidence.

$$l = \left(\frac{\varepsilon_d \varepsilon_s}{\varepsilon_d + \varepsilon_s} \right) s_d + \left(\frac{\varepsilon_d \varepsilon_s}{\varepsilon_d + \varepsilon_s} \right) s_s$$

$$w = \left(\frac{\varepsilon_d}{\varepsilon_d + \varepsilon_s} \right) s_d - \left(\frac{\varepsilon_s}{\varepsilon_d + \varepsilon_s} \right) s_s$$

where $\varepsilon_d = -W_d L_d'/L_d > 0$ and $\varepsilon_s = W_s L_s'/L_s > 0$ denote the (absolute) wage elasticities of demand and supply, respectively.

The equilibrium amount of R&D activity (as measured by hired R&D workers) increases identically for a 1% increase in subsidies on the demand side and a 1% increase in subsidies on the supply side. Hence, it does not matter whether subsidies are given to the demand or to the supply side of the R&D labour market for the total amount of R&D carried out in a competitive economy (although it does matter for wages). Both are in principle equally potent channels to boost R&D.

The effectiveness of R&D policies to generate additional R&D is determined by the elasticities of both the demand and supply side through the factor $\varepsilon_d\varepsilon_s/(\varepsilon_d + \varepsilon_s)$. Clearly, if either one of the sides of the market is completely inelastic ($\varepsilon_d = 0$ or $\varepsilon_s = 0$) any policy is impotent to increase R&D activities. Further, the larger the product of the elasticities relative to the sum, $\varepsilon_d\varepsilon_s/(\varepsilon_d + \varepsilon_s)$, the more effective R&D policy is to generate additional R&D. This implies that if either one of the elasticities increases, the impact of policy on the equilibrium level of R&D increases as well. Therefore, the impact of R&D policies goes up if the sum of demand and supply elasticities increases. The conclusion is that both the elasticities of demand *and* supply are crucial in determining the effectiveness of policy to boost R&D. One cannot look at one side of the market in isolation.

To summarise, in order to determine the effectiveness of policy to promote R&D it is important to know how much the equilibrium level of R&D responds to policies. In a competitive labour market it does not matter whether the supply or demand side of the market is stimulated. If either one side of the market is completely inelastic any policy is ineffective. Therefore, we need to know whether the elasticities of demand and supply for R&D are not equal to zero.

The elasticity of demand for R&D

The demand for R&D is determined by wages of R&D workers, but also by the costs of machines, laboratories and so on. Nevertheless, wage costs constitute the bulk of total R&D expenditures. Hence, demand for R&D is indeed importantly affected by wage costs of R&D workers. Cornet (2001) finds that the demand for R&D is to a certain extent quite elastic. His findings suggest that the elasticity of R&D with respect to the WBSO subsidy is at least 0.4 for small firms in the unfavourable scenario and at most 3.5 for big firms in the favourable scenario. These findings are in the ballpark of empirical findings.[33] Hence, a unit demand elasticity of R&D with respect to wages of R&D, seems empirically plausible. Then a 1% decrease in wage costs generates a 1% increase in demand for R&D workers.

The elasticity of the supply of R&D workers

The supply elasticity of R&D workers is driven by three decision margins. First, individuals decide upon how many hours to work. This is the *intensive* labour supply margin. Second, on the *extensive* labour supply margin, individuals decide whether to supply their labour in R&D-related jobs or in other jobs. The third labour supply margin is whether to enrol in S&E education or not. Elasticities of labour supply on the intensive margin are typically small. Goolsbee (1998) estimates the (uncompensated) wage elasticity with respect to hours worked for US R&D workers and finds elasticities in the order of 0.1 – 0.2. These figures imply that hours worked in R&D will increase with 1 – 2 % for a wage increase of 10 %. These estimates of the labour supply elasticity are typically found in micro-econometric studies of labour supply, see also Blundell and MaCurdy (1999). Elasticities of labour supply on the extensive margin are probably larger. Unfortunately, empirical evidence for the elasticity of the supply of labour in R&D-jobs is not available. Ideally, we would like to know how much the supply of R&D workers increases when wages for R&D workers increase relative to other occupations. However, from the empirical literature we do know that the extensive margin for the decision whether to participate on the labour market or not, is typically much more elastic (Saez, 2002). Empirical estimates of these elasticities are in the order of 0.5 – 1. In the long run, the decision whether to pursue an S&E study is important as well. Hence, the elasticity to enrol in (S&E) education is important here. In general, the price elasticity of the demand for higher education is low (CPB, 2003). However, we do not know whether this low elasticity also applies to subsidies which aim to make S&E education more attractive relative to other studies. In addition, the effectiveness of school projects aimed at changing educational decisions, such as intended in the current Delta plan Beta/technology, has not been analysed in studies which use a credible evaluation design. As such, there is no credible evidence on the elasticity of the enrolment in S&E studies. A recent study by Ryo and Rosen (2004) shows that the supply of S&E workers adjusts with some delay to changes in relative wages. Hence, this study suggest that the supply of S&E graduates is not equal to zero.

Although the evidence on the elasticities is fragile we may conclude that demand and supply for R&D are not completely inelastic. This means that R&D policies can increase domestic R&D activity.

[33] This can be computed as the change in R&D (as a percentage of total R&D investments) after the WBSO was introduced. In the most favourable scenario this was 22% and the least favourable scenario this was 12%. The decrease in total costs of R&D has been at least 6% for big companies who mainly benefit from the marginal subsidy of 14% for R&D personnel and potentially increasing to 30% for small firms who benefit from the 40% subsidy on the initial 90 thousand euro wage costs (assuming that total wage costs are 50% of total costs of R&D in big firms and 75% in small firms).

9.2 Government failure

Whether the government should intervene to stimulate R&D activities by means of R&D subsidies depends on the balance between the benefits and costs of such intervention. Wage subsidies for R&D personnel or education subsidies for S&E students may appear equivalent in boosting the aggregate level of R&D as we have shown in the previous section. The equilibrium level of R&D is not affected by which side of the market receives the subsidy.

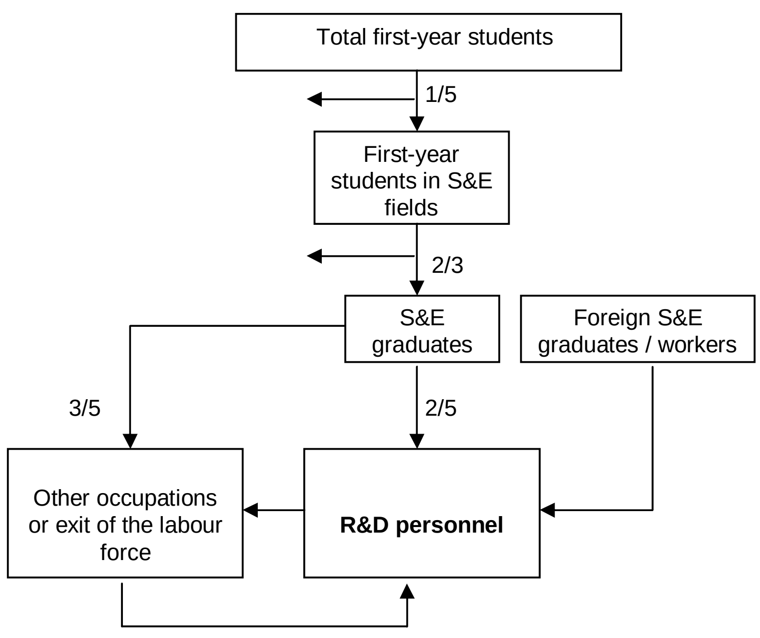
However, if the government is going to intervene in the market on the basis of these insights, we will have to take into account so called government failures. It may not always be possible to design policies at reasonable costs which effectively target the goal of the policy. So what mix of demand and supply side policies to choose, crucially depends on the government failures involved in both subsidies on the wage costs for R&D workers and subsidies on S&E education. A substantial part of subsidies might 'leak away' due to lack of additionality, substitution effects and fungibility problems. These problems are present both with subsidies on the demand for R&D and the supply of R&D workers (see also Cornet, 2001):

- *Lack of additionality*. This is related to a low elasticity of demand or supply. If the elasticity of demand for R&D is lower, more subsidies are given to firms and projects which would have conducted R&D in the absence of subsidies. In other words, subsidies generate no additional R&D. We have seen above that the demand for R&D may to some extent be quite elastic. At the supply side, subsidies on S&E education will mainly benefit the graduates who decides to enrol anyhow.
- *Substitution*. Subsidised R&D activities generally replace R&D activities which are not being subsidised. For example, stimuli on R&D production tend to focus solely on 'hard' innovations, i.e. technological innovations. This may come at the cost of non-technological innovations like innovations in services (for instance in fields like strategy, marketing or organisation). These 'soft' innovations can be potentially carried out by non-S&E graduates like economists or jurists. Indeed, focusing too much on R&D would imply a shift of (human) resources away from soft innovations. This is especially true if both activities call upon the same occupational group. At the supply side, heavily subsidised S&E education may attract too many marginal students who have no socially beneficial R&D career prospects.
- *Higher wages*. If the supply of knowledge workers is inelastic, subsidising R&D activities leads to higher wages rather than additional R&D activities. As we have shown, labour supply may not be completely inelastic in the short-run. The short-run elasticity is roughly equal to the long-run elasticity if the Dutch labour market remains closed to foreigners. In the long-run, and in the absence of foreign supply of R&D workers, 25% of increased subsidies may leak away due to higher wages (Cornet, 2001).

- *Fungibility* (a labelling problem). Companies can charge costs which have nothing to do with R&D as if they were R&D expenses, and thus be eligible for a subsidy. A reported increase in R&D might in fact only be a re-labelling of old activities. Empirical work suggests that this problem may be substantial and about 10% of total outlays on R&D subsidies leak away on that account. In fact, re-labelling might also occur with activities that were R&D in the first place, but not labelled as such before the subsidy or tax incentive. At the supply side, higher educational institutions may engage in re-labelling of educational costs between fields of study so as to attract more funds from the central government if the government decides to heavily subsidise S&E education.

Hence, government failure is important for both subsidising the demand and supply of R&D activities. Both demand and supply side policies may suffer from lack of additionality, substitution, and fungibility problems. Based on empirical evidence it is not clear which policy suffers most from these problems. However, there is one important difference. Demand side policies are directly targeted at increasing R&D activity whereas supply side policies generally are not. Several steps have to be taken before supply side policies, like school projects aimed at changing educational decisions, translate into an increase of R&D. This is illustrated in Figure 9.2 which shows the supply chain from university or HBO to R&D-jobs.

Figure 9.2 The supply chain from university to R&D



About 40 % of all S&E graduates finds a job in R&D. Hence, subsidies on enrolment in S&E studies are not well targeted and about 60 % leaks away in the supply chain. This leakage of resources will be smaller if S&E graduates, who do not enter R&D jobs, enter jobs which are also characterised by spillover effects. However, the external effects of S&E graduates in other jobs are unknown. Demand side polices, in contract, focus directly on an increase in R&D-activity. In addition, the time between the subsidy and the increase in R&D is much smaller for demand side policies than for supply side policies. For the latter to be effective it takes at least several years because graduating from S&E studies takes time.

The main conclusion is that demand side policies are preferable to supply side policies because they are more directly targeted at increasing R&D activity.

9.3 The internationalisation of R&D production

R&D becomes more and more an international activity and the market for S&E workers increasingly becomes a global one. On the one hand, Dutch firms have access to an international supply of S&E workers. On the other hand, firms can relocate R&D activities to countries with the largest comparative advantage in doing R&D. This internationalisation of R&D production will lead to an efficient relocation of S&E workers and R&D firms. What does this mean for the effectiveness of demand and supply policies which aim to increase domestic R&D?

In general, international forces can change the elasticities of demand and supply for R&D which changes the effectiveness of policies (see section 10.1). For instance, opening up international labour markets for R&D workers will make it easier for firms to actually find such workers if demand increases. This increases the effectiveness of a subsidy on the demand for R&D. Another consequence of the internationalisation of the supply of R&D workers may be that domestic supply side policies become less effective. Suppose that the government wants to make S&E education more attractive relative to other studies. As a result of the internationalisation domestic S&E workers have to compete with a growing influx of cheaper foreign S&E workers. The growing competition of foreign workers makes it less attractive to enrol in S&E studies which undermines the effectiveness of supply side policies. And even if students enrol in S&E studies, they may not take R&D jobs if other jobs are more attractive, in term of wages or other aspects. If internationalisation of R&D production causes the market clearing wages for R&D workers to fall below that of other professions, the only effective way to stimulate S&E graduates to choose R&D jobs is to subsidies those *jobs*.

10 Conclusions

This study started from the widely felt concern about shortages of science and engineering graduates. These shortages can seriously limit the innovative capacity of the Netherlands, hamper growth of productivity and may call for policy interventions. This study focuses on three questions:

1. Why should the government intervene in the labour market for science and engineering graduates?
2. What do we know about supply and demand in the Dutch labour market for science and engineering graduates?
3. Which policies are the most effective in increasing R&D-activity?

The need for government intervention

Unbalances between supply and demand can in principle be solved by market forces. So why should the government intervene in the market for science and engineering graduates? The main economic motive for intervention in this labour market is that science and engineering graduates are important in R&D activity. Many studies provide evidence for spillover effects of R&D-activities. From a societal perspective, firms will under invest in R&D because they can not fully appropriate the returns on their investments. Hence, government interventions that increase R&D activities of private firms can raise domestic wealth. Shortages in the supply of science and engineering graduates may hamper R&D-activity and this may damage the growth of productivity of the economic process at large. Government intervention in the labour market for science and engineering graduates may be legitimate to internalise the external effects from R&D-activity. The economic literature does not provide evidence for spill over effects of S&E graduates in other activities. This does not mean that these effects are absent, but that we do not know whether these effects occur.

The current labour market

Demand

The demand for science and engineering graduates which stems from public and private R&D expenditures is quite stable. From the beginning of the 1980s, the Netherlands spends approximately 1.9 % of GDP on R&D. The five large Dutch multinationals are the key players in private R&D (one third of total R&D employment). In the last 25 years their share of the total R&D activities in the Netherlands decreased. Moreover, the Dutch share in their worldwide R&D activities decreased. This is the result of expansion of activities abroad and not the result of a relocation of activities. At the same time, other firms expanded their R&D activities in the Netherlands.

Supply

Since 1975, the number of graduates from higher education has more than doubled. The share of S&E graduates from university decreased from 28 % in 1975 to 20 % in 2002. In higher vocational education this share decreased from 22 % in 1975 to 20 % in 2002. The lower shares of S&E graduates mainly originate from a composition effect due to the increased enrolment of female students. The developments in the supply of S&E graduates sharply contrast with those of graduates in economic studies. Their shares rose by 8 %-points for university graduates and 25 %-points for graduates from higher vocational education.

S&E graduates in R&D

In 2002 one out of three S&E graduates worked in core R&D. This share has decreased by 8 %-points since 1993. R&D is primarily done by young workers, 43 % of S&E graduates between 25-29 years works in R&D against 27 % of 45-55 years. Internationalisation is important in public and private R&D. The share of foreign workers in public and private R&D is substantial and seems to be increasing. On the other hand, the share of Dutch graduates working abroad is increasing, especially S&T graduates interested in research jobs. Compared to other countries the Dutch shares on inflow and outflow seem relatively low.

The interaction of demand and supply

To investigate the interaction of demand and supply of S&E graduates we looked at a wide range of labour market indicators: vacancies, unemployment rates, wages, labour market participation and weekly working hours. The main finding from this empirical analysis is that we do not find evidence for a tight labour market of S&E graduates. None of these indicators suggests a tight labour market for science and engineering graduates in the recent past. Instead, the data suggest that the labour market position of S&E graduates has been weakening since 1996. This holds both for a comparison with all other graduates and specifically for a comparison with economic graduates. Especially the changes in the wage level are remarkable. The wages of S&E workers have declined compared to all other higher educated workers since 1996. At the university level, the relative wage position of S&E graduates deteriorated by 5 % and at the HBO level by 3 %. In addition, since 1979 the wages of S&E workers with a university degree have declined compared to the wages of economic graduates. While in 1979 the wage levels were about equal, in 1996 economic graduates earned 9 % higher wages. This wage differential further increased to 12 % in 2002. In view of the differing developments in the supply of graduates this is a surprising result which suggest that the demand for economic graduates has been much larger than the demand for S&E graduates.

Other explanations, like unobserved characteristics of S&E graduates, are less plausible since the main finding is a change over time in the relative wage level of S&E graduates. A wage differential between S&E graduates and economic graduates can be related to differences in demand and supply conditions but also to other unobserved characteristics of S&E graduates, like skills in wage negotiations. However, the latter factors seem less relevant if we consider changes in wage levels. If S&E workers are comparable over time non-observed characteristics of S&E graduates can not explain the deterioration of the relative wage position of S&E workers.

The fact that these labour market indicators do not provide evidence for shortages of S&E graduates poses a puzzle. How can we explain that employers experience hiring problems when all our labour market indicators suggest the opposite?

The S&E puzzle: why do employers experience hiring problems?

A possible explanation may be found in the internationalisation of R&D activities. The market for S&E graduates becomes more and more international as a large share of R&D activity is done by multinational firms. This has major implications for demand and supply of S&E graduates in the Netherlands. On the one hand, Dutch firms have access to an international supply of S&E workers and this puts downward pressure on wages because the wage level is increasingly determined in an international market. On the other hand, firms may relocate R&D activities to countries with the largest comparative advantage in doing R&D. The analysis of demand and supply provides evidence that this internationalisation process is going on. In recent years we observe an increase of foreign S&E graduates in Dutch universities and private R&D. At the same time, the share of Dutch S&E graduates working in R&D has decreased by 8 %- points since 1993. Moreover, the share of Dutch graduates from higher education working abroad is increasing, especially S&T graduates interested in scientific jobs. This is in line with a growing internationalisation of the market for S&E graduates. As a result, wages for Dutch S&E graduates will remain at the international level for S&E graduates. If this level is below the market clearing level in competing parts of the Dutch labour market, firms will have problems with hiring Dutch S&E graduates. In that case, they will have to substitute domestic S&E workers with foreign S&E workers, even if this implicates higher costs and more uncertainty about the stability of the working relation. The other side of this story is that firms will relocate their activities if the dependence on foreign workers becomes too large. The observation that Dutch multinationals do not expand R&D in the Netherlands but abroad seems in line with this. But this can also be related with the higher economic growth in other parts of the world. In an international market firms move their activities to countries with comparative advantages. It seems clear that internationalisation is important in the market for R&D. In addition, the labour market for S&E graduates seems more international than the labour markets for other higher educated workers. Nevertheless, it is not clear if internationalisation is the major explanation of the S&E puzzle. For instance, can internationalisation really explain that since 1996 wages of S&E workers compared to all other graduates have fallen by 5 % at the university level and 3 % at the HBO level. Hence, it seems safe to conclude that internationalisation may be part of the solution of the S&E puzzle but we are not sure if this is the whole story.

The level of aggregation of the data

Another factor that may explain the divergence between the experiences of employers and the empirical findings is the level of aggregation of our data. In most of the analysis we focus on the whole sample of higher educated S&T graduates. At a more disaggregated level the picture might be different. In some disciplines it might be difficult for employers to hire graduates. In other disciplines it might be difficult for graduates to find a job. Some empirical findings are in line with this explanation. The analysis of wage differentials shows that at the higher vocational level there is a large difference in the rewards of science graduates and transport graduates. In addition, since 1991 the enrolment shares of several disciplines have changed substantially. If this explanation is important the main issue would be to improve on the match between the supply and demand of S&E graduates. This differs from the current policy targets aimed at increasing the number of S&E graduates by 15 %.

Future shortages?

Labour market forecasts indicate that the expected demand exceeds the expected supply for almost all types of higher education, including S&E studies. This is driven by the ageing of the labour force. What will be the impact on R&D activity? First, R&D is typically done by young employees. Occupations with a relatively young work force will be less affected by the replacement demand induced by workers that are retiring. As such, the replacement demand for R&D workers may be smaller than in other occupations. Second, the impact on R&D activity will also depend on the changes in competing parts of the labour market. Relative scarcity of S&E workers in the future is more informative because this determines relative wages and thereby influences enrolment decisions and choices of job type. The predicted vacancy rate in S&E studies is lower than in some other disciplines at both higher vocational and university education. As a consequence, we may expect that market forces are stronger in attracting students and graduates to non-S&E types of education. In addition, the internationalisation of the labour market for S&E graduates will prevent the wages of S&E graduates to adjust to changes in domestic scarcity, which may reinforce the decrease of the relative demand for S&E graduates. This could undermine the wage prospects of S&E graduates even more.

Which policy is the most effective for increasing R&D-activity?

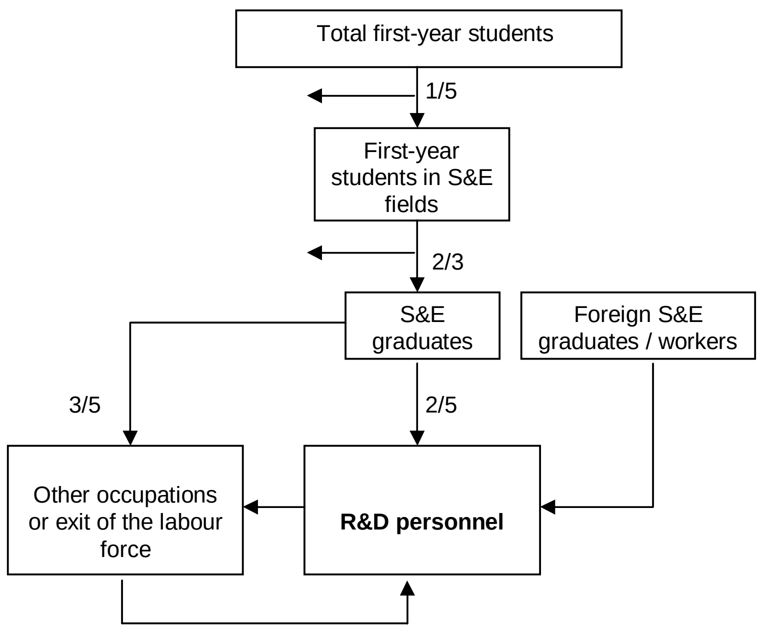
Spill over effects to other economic activities legitimate government intervention to increase R&D activity in the Netherlands. But what should the government do? Which policies are the most effective for increasing R&D-activity in the Netherlands? The government can try to increase R&D activities with supply side policies and with demand side policies. Supply side policies focus on increasing enrolment and graduation in S&E studies. Typical instruments are financial incentives (lower tuition fees) or projects aimed to increase interest in technology (like making R&D or research jobs more attractive) or to promote the graduation rate in S&E studies. Demand side policies focus on the demand for R&D by private firms. Typical instruments are

R&D subsidies, like the WBSO. The choice between supply side and demand side policies depends on the degree of government failure in stimulating R&D activity.

Government failure

Not all government instruments are successful in realising the targets that are aimed for. This so-called government failure is important for both subsidising the demand and supply of R&D activities. However, the effectiveness of demand side polices seems to be much larger than the effectiveness of supply side policies. The main reason is that demand side policies are directly targeted at increasing R&D activity whereas supply side policies generally are not. Several steps have to be taken before supply side policies, like school projects aimed at changing educational decisions, translate into an increase of R&D. This is illustrated in Figure 1.1 which shows the supply chain from university to R&D-jobs.

Figure 10.1 The supply chain from university or HBO to R&D



Approximately 40 % of all S&E graduates find a job in R&D. Hence, subsidies on enrolment in S&E studies are not well targeted and about 60 % leaks away in the supply chain. This leakage of resources will be smaller if S&E graduates, who do not enter R&D jobs, also enter jobs with spillover effects. However, the external effects of S&E graduates in other jobs are unknown. Demand side polices, in contract, focus directly on an increase in R&D-activity. In addition, the time between the subsidy and the increase in R&D is much smaller for demand side policies than for supply side policies. For the latter to be effective it takes at least several years because graduating from S&E studies takes time. Demand side policies can not only increase R&D activity but can also increase the attractiveness of S&E studies.

International dimension

The internationalisation of R&D production will lead to an efficient relocation of S&E workers and R&D firms. What does this mean for the effectiveness of demand and supply policies which aim to increase domestic R&D? In general, international forces can change the elasticities of demand and supply for R&D which changes the effectiveness of policies. For instance, opening up international labour markets for R&D workers will make it easier for firms to actually find such workers if demand increases. This increases the effectiveness of a subsidy on the demand for R&D. Another consequence of the internationalisation of the supply of R&D workers may be that domestic supply side policies become less effective. Suppose that the government wants to make S&E education more attractive relative to other studies. As a result of the internationalisation domestic S&E workers have to compete with a growing influx of cheaper foreign S&E workers. The growing competition of foreign workers makes it less attractive to enrol in S&E studies which undermines the effectiveness of supply side policies. And even if students enrol in S&E studies they may not take R&D jobs if other jobs are more attractive, in term of wages or other aspects. If internationalisation of R&D production causes the market clearing wages for R&D workers to fall below that of other professions, the only effective way to stimulate S&E graduates to choose R&D jobs is to subsidies those *jobs*.

Policy options

The 'Delta plan beta-techniek' is a mixture of interventions aimed at various targets. The main motive for government intervention in the labour market for S&E graduates can be found in the spillover effects of R&D production. Hence, the main target of these government interventions should be to increase R&D-activity in the Netherlands.

1. Define policy in terms of R&D objectives.

The case for demand side policies is stronger than the case for supply side policies. Demand side policies are directly targeted at R&D production whereas supply side policies are not. Even if supply side policies succeed in increasing enrolment in S&E studies, graduates might choose not to work in R&D if other jobs are more attractive. Hence, a large share of the supply side subsidies will leak away in the supply chain. The internationalisation of the labour market for R&D workers further reduces the effectiveness of such policies.

2. Be cautious with supply side policies, because there might be a lot of government failure.

The government failure with supply side policies will be smaller if there are also external effects of S&E graduates in other activities than R&D. However, there is no empirical evidence on this and there is also no empirical evidence on external effects of graduates from other disciplines. The empirical literature on labour supply suggests that the elasticity of the decisions on the type of job and the number of hours worked is higher than the elasticity of enrolment in education. Policies that focus on more elastic margins will suffer less from government failure. Hence, the government failure will be smaller for interventions further down the supply chain such as ‘attractive jobs’ and ‘attractive location’.

3. The effectiveness of the current policy program ‘Deltaplan beta-techniek’ can be enhanced by increasing the emphasis on interventions further down the supply chain like ‘attractive jobs’ and ‘attractive location’. Instruments that focus on the most elastic margins of the decision on the supply of labour – working more hours in S&E jobs and on choosing between working in R&D and in other jobs (e.g. through special tax credits for S&E workers) – are the most effective.

The current knowledge on the impact of supply side interventions is very limited. There is no convincing evidence on the impact of various projects which aim to increase enrolment and graduation in S&E studies. Moreover, private firms actively support these projects. A sensible way to approach in this context could be to generate knowledge on the impact of these projects. This can be done by choosing experimental designs for the various public - private initiatives and evaluating their impact. If the government wishes to stimulate supply with various projects aimed at increasing enrolment and graduation in S&E studies:

4. Formulate policy measures in such a way that they can be evaluated and that credible evidence can be generated on the impact of various projects.

For instance, to find out to what extent participation in S&E courses can be boosted with additional grants, a controlled experiment can be done. In this experiment a randomly selected group of final-year secondary school pupils is offered additional student grants, whereas a control group is not. The effect of the additional student grants can then be measured by comparing the participation in technical courses in the experimental group with the participation in the control group.

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Appendix: Definitions and nomenclatures in the data sets

Definition of S&E fields using the SOI-1978 nomenclature

The Dutch Labour Market survey (EBB) distinguishes four fields of study in higher education: 1) science and engineering, 2) economics, 3) health care and 4) others and unknown. This distinction uses the SOI-1978 (*Standard Onderwijsindeling* 1978) nomenclature[34]. In the SOI nomenclature, the first digit represent the level of education (5 indicates higher vocational education, 6 indicates university and 7 indicates post-university degrees). The second and third digit describe the field of study. The Dutch Labour Market Survey categories are constructed as follows (where the SOI numbers indicate the second and third digits):

- Science and Engineering: SOI 20-49, i.e. agriculture, mathematics and physics, engineering, transport.
- Economics: SOI 60-66, i.e. economics, trade and administration, law and management.
- Health care: SOI 05-16 (pedagogics, humanities, theology), SOI-50-54 (medical and paramedical), SOI 70-93 (socio-cultural fields, personal and social care, art, public order and security)
- Others: SOI 00-01 (general education) and SOI 95-99 (others, unknown).

Further, the EBB combines the 1st digit levels 6 and 7 within the university level. To conclude, S&E fields in the Dutch Labour Market survey include agriculture but exclude medical sciences.
In the LSO dataset, 5-digits SOI-1978 nomenclatures are used to indicate the type of education. We construct the dummy variables using the same classification as the EBB.

The data

The report draws from a various number of data sources, ranging from basic statistics from the Statistics Netherlands (CBS) to two large surveys, also from the CBS. The latter two are used for econometric analysis, in chapter 6. The first data set is the Wage Structure Survey (LSO, or *Loon Structuur Onderzoek*) which is our main source for wage data. The LSO contains, among others, individual data on wages, education, industry and job characteristics and data such as gender and age of the respondent. The wage data are obtained partly through the yearly survey on employment and wages among firms (*Enquête naar Werkgelegenheid en Lonen*) and partly through administrative sources on insured people (*Verzekerende Administratie*, VZA).

[34] The SOI-1978 nomenclature was originally closely related to the international ISCED nomenclature, but less so since it was revised twice (in 1998 and 2003). See for more information CBS (2003).

Unfortunately, the LSO is not an annual data set. The most recent LSO available contains data over 2002; the LSO prior to that dates back to 1997. We also use data from the surveys of 1979, 1985 and 1996 and focus on individuals between 16 and 64 years old.

The second source is the yearly Labour Market survey (the EBB, or the *Enquête Beroepsbevolking*). This data set contains many indicator of an individuals' position on the labour market, like employment status, number of hours worked, etcetera. The drawback however is that it does not contain wage data. We use the EBB for analyses of indicators such as participation rates.

In addition, we use data of the vacancy survey of Statistics Netherlands and forecasts by ROA.