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Crossing borders: when science meets industry

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Abstract in English

Economic growth is ultimately driven by advances in productivity. In turn, productivity growth is driven by R&D and by utilisation of the public knowledge pool. This public knowledge pool is generated by universities and public research institutions. Underutilisation by firms of results from public research can reduce economic growth, and the question then emerges how to bring science to the market. In this report we explore whether in Europe public knowledge is underutilised by firms, and investigate the quantitative importance of various knowledge transmission channels (such as publications, informal contacts, consulting). Next we study characteristics of universities and firms that may prevent an effective knowledge transfer. Finally we look at a number of policy initiatives designed to foster science-to-industry knowledge spillovers in the Netherlands and a selection of other countries.

Key words: science-to-industry knowledge spillovers, incentives, policy initiatives

Abstract in Dutch

Economische groei wordt uiteindelijk bepaald door de productiviteitsontwikkeling. De productiviteitsgroei wordt gedreven door R&D en benutting van de publieke kennisvoorraad. Deze publieke kennisvoorraad wordt voortgebracht door universiteiten en publieke onderzoeksinstellingen. Onderbenutting door bedrijven van de resultaten van publiek onderzoek kan de economische groei beperken, en de vraag dient zich dan aan hoe wetenschap naar de markt kan worden gebracht. In dit rapport onderzoeken we of in Europa de publieke kennisvoorraad wordt onderbenut door bedrijven, en proberen we inzicht te krijgen in het kwantitatieve belang van de verschillende kanalen van kennistransmissie (zoals publicaties, informele contacten, consultancy). Vervolgens onderzoeken we de karakteristieken van universiteiten en bedrijven die een effectieve kennisoverdracht in de weg kunnen staan. Tenslotte kijken we naar een aantal beleidsinitiatieven die ontworpen zijn ter bevordering van kennisspillovers tussen universiteiten en bedrijven in Nederland en een aantal andere landen.

Steekwoorden: kennisoverdracht tussen universiteiten en bedrijven, prikkels, beleidsinitiatieven

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

Contents

Preface

This project is about science-industry interactions in research: how to bring scientific knowledge to the market? At least to some extent, academia and industry are separate worlds, and a widely heard concern is that knowledge transmission between the public and private sector is too limited. In this document we study how to foster the border crossings between science and industry.

The expert committee for this project has provided critical, thoughtful, and constructive comments. The committee consisted of Joke van den Bandt (VNO-NCW), Karin Jongkind and Jeffry Matakupan (both from the Ministry of Economic Affairs), Jan van Miltenburg (Advisory Council for Science and Technology Policy, AWT), Niek Nahuis and Mark Roscam Abbing (both from the Ministry of Finance), Frank van Oort and Roderik Ponds (both from the Netherlands Institute for Spatial Research and Utrecht University), Gerard van Oortmerssen (TNO-Telecom), and Bart Verspagen (Eindhoven Centre for Innovation Studies).

The study also benefited from discussions with Diederik Zijderveld (NWO), Jeroen Bartelse and Esther Stiekema (VSNU), and Frank van den Berg, Marjan Konings, Chris Mombers, and Wouter Segeth (Technology Foundation STW), Jan de Wit (Akzo Nobel and Radboud University Nijmegen), Hans de Boer and Lieuwe Boersma (both from Delft University of Technology). Andreas Blom (The World Bank) has given many important suggestions and comments on an early draft of this report, which has led to a substantial revision.

Conference participants at the Regional Studies Association (Denmark) and the International Institute of Public Finance (South-Korea) provided helpful suggestions. The critical comments by participants of a CPB symposium on this topic, and especially by the discussants Anton Franken (Technology Foundation STW), Thomas Grosfeld (Ministry of Economic Affairs) and Diederik Zijderveld (Innovation Platform) are gratefully acknowledged.

The contents of this report remains our own responsibility, and does not necessarily reflect the opinion of the members of the expert committee, any other persons mentioned above or the organisations they represent.

Finally, CPB colleagues Maarten Cornet, Taco van Hoek, Fré Huizinga, and Dinand Webbink provided helpful comments.

Henk Don, director CPB

Summary

A widely heard concern in the member countries of the European Union is that while their universities are productive in terms of high quality publications, firms in Europe make relatively little use of the newly created scientific knowledge. At the same time, it is believed that in the US the connections between firms and universities are much stronger. This ‘European knowledge paradox’ is of great concern to European policymakers, as limited knowledge spillovers between science and industry reduce the potential for innovation and economic growth. Many countries have therefore undertaken initiatives to improve the university-to-industry knowledge transfer.

The current report is about science-industry interaction in research: how to bring scientific knowledge to the market? The focus is on knowledge transfer from universities to firms. The research question is subdivided into three parts:

1. Do the facts support the policy concerns about a ‘European knowledge paradox’?
2. What are the potential barriers to interaction on the side of universities and on the side of firms?
3. What kinds of policy initiatives have been taken to alleviate the various barriers, and what are the lessons from these experiences?

Empirical evidence on science-industry interaction

Do the facts support the policy concern of a ‘European knowledge paradox’? Three issues emerge in such an empirical analysis. First, to which extent is the European knowledge paradox a real problem? Is the US performance with regard to science-industry knowledge transmission better than in the EU-countries? Second, what are the means of connection (i.e., the transmission channels) between science and industry? Insight into the quantitative importance of transmission channels may help to design policy instruments. Finally, how important is science-industry interaction for macroeconomic performance? The latter is the subject of ongoing concern for the government.

Evidence on European knowledge paradox is mixed and incomplete, although there are some indications of weak points

A comparison across a selection of OECD countries reveals that the evidence of a European knowledge paradox is mixed and incomplete. It is mixed, as the ranking of the countries varies strongly across indicators of science-industry interaction. Moreover, indicators are lacking for a number of important channels of interaction, particularly for the US. On three out of six indicators for which data on the US are available, the country ranks first. But it seems to be an overstatement to use this as evidence for the existence of a European knowledge paradox.

Next, we explore science-industry interaction in the Netherlands, compared to other European countries. An examination of the use of sources of information by R&D managers (the European Community Innovation Survey) shows that there are both strong and weak points in science-industry knowledge transfer in the Netherlands. The data reveal that only few firms mention universities to be an important source of information. The intensity of science-industry interaction depends on the size of the firm. Large companies show a greater propensity to collaborate with the public research sector than small and medium-sized firms.

Public and private knowledge transfer channels are complements

From US evidence it appears that the most important transmission channels are the public ones (such as publications and reports). However, informal information channels and consulting, which involve personal contacts, are also important. It appears that these private channels are often used in conjunction with the public channels. The distinction between public and private transmission channels overlaps with the distinction between codified and tacit knowledge. Publications in scientific journal transmit codified knowledge. Transfer of tacit knowledge requires personal contact. The complementarity between public and private knowledge transmission channels therefore suggests that codified and tacit knowledge are complements in the transmission of knowledge.

Science-industry interaction is intertwined with macroeconomic performance

Cross-country data from the Global Competitiveness Report show that science-industry interaction is closely intertwined with a range of other indicators for the knowledge economy, and with macroeconomic performance. First we observe that countries where firms spend heavily on R&D tend to be countries with high per capita incomes. Second, the data show that countries where the respondents indicate that companies spend heavily on R&D also tend to be countries with intensive and ongoing research collaboration between the private sector and local universities. Finally, strong correlations are found between the intensity of university/industry research collaboration and a range of other indicators, such as the quality of research institutions, public R&D support, intellectual property protection, and venture capital availability. It should be stressed that these observed correlations do not allow us to draw inferences about causality. For instance, intensive science-industry interaction could encourage private R&D investments, but it could also work the other way: companies heavily investing in R&D seek for research collaboration with the public sector. This is important, as it implies that policies to strengthen science-industry interactions may not be effective when causality runs the other way. In that case, more intensified R&D collaborations would be a side-effect of policies to encourage private R&D investments. Further research should improve our understanding on the causal impact of science-industry interaction.

Potential barriers in science-industry interaction

Which factors could hamper science-industry interaction? There may exist barriers to interaction on the side of universities and on the side of firms. From the economic literature, the report derives a number of potential barriers to interaction. These barriers are identified by studying certain characteristics, in particular the incentive structure, of the universities and firms. Probably the most important barriers are an ill-designed reward structure for scientists in the public research sector, and a lack of absorptive capacity of private firms.

Barriers in the public research sector: Reward structure of scientists does not encourage activities to bring science to the market

The reward structure of scientists and their academic careers depend on publication records. Scientific ambition is reflected in a publish or perish culture. This 'norm of disclosure' from the scientific community may clash with the norm of secrecy common to the business world. But even without such a cultural clash it is safe to state that scientists experience little or no incentives to engage in science-industry interaction, while they experience high-powered incentives to publish. Besides, two other potential barriers may exist within universities. First, the culture within universities may not encourage entrepreneurial activities, which is considered to be outside the scope of an academic. However, the often-mentioned drawbacks of a more entrepreneurial attitude of scientists (i.e., problems with the disclosure of research results and shifts in the agenda away from fundamental to more applied research) do not receive robust empirical support. A final barrier to science-industry interaction in the public research sector is a large difference between the research agendas of universities and firms. The funding structure of universities affects the public research agenda, and thereby the potential for science-industry interaction. While this limits the opportunities for interaction, some public-private difference in research specialisation may be justifiable in terms of knowledge externalities and public tasks. Winding up, the reward structure seems to be the most important barrier in the public sector. Entrepreneurial activities by scientists will also be related to this reward structure, and the problem of diverging research agendas in the public and private domain can be reduced by making it attractive for scientists to collaborate with industry.

Barriers in the private sector: Lack of absorptive capacity of firms may harm utilisation of scientific knowledge

Lack of absorptive capacity within firms can form a large barrier to use knowledge developed elsewhere. Absorptive capacity is a function of the firm's investment in R&D, and of its connection to the scientific community. A firm investing in R&D and in networks with the academic community can benefit more from the public knowledge pool. To date, our understanding of the connection between absorptive capacity and private R&D efforts is very limited. A second barrier for firms to utilise scientific knowledge relates to capital market imperfections due to information asymmetries. Firms may find it difficult to obtain credit to finance their research projects. A third potential barrier comes from agency problems within the firm. For instance, the management may prefer an ‘easy life’ and postpone innovation or adoption of new technologies. To sum up, a lack of absorptive capacity may be the dominant barrier in firms to effectively interact with the scientific community. The problem of credit market imperfections can partly be solved by the market, for instance by providing ‘smart’ venture capital. Internal agency problems cannot be solved directly through government intervention, although indirect policies (such as competition policy) could reduce these problems.

Policy initiatives and options to promote science-industry interaction

What kinds of policy initiatives have been taken to alleviate the various barriers, and what are the lessons from these experiences? The report discusses a number of domestic and foreign policy initiatives. The various policy interventions are classified by their focus to remove or reduce a specific barrier identified within the public research sector or the firm. While policy interventions seem to cover all the potential barriers we have identified, assessment of these policies should be based on their effectiveness in terms of improved science-industry knowledge transmissions.

Policy interventions, part I: Reducing specific barriers

Provide direct incentives for scientists to engage in science-industry interaction

Scientists may be encouraged to try and bring their inventions to the market by means of direct financial incentives. These financial rewards could for example be connected to patenting activities. The Bayh-Dole Act in the US allows American universities to patent and license their inventions from federally funded research. From the US experience we learn that revenue-sharing may significantly affect the scientist’s propensity to patent. In the Netherlands, universities have always been free to patent results from publicly funded research. However, direct incentives for scientists to commercialise their findings are largely absent. This may explain why Dutch universities produce relatively few patents.

Provide preconditions for entrepreneurship in academia

Scientists often meet many practical problems when trying to bring their ideas to the market. Professional guidance and technical assistance of scientists with marketable inventions can help to commercialise public research. Technology Transfer Offices (TTOs) affiliated at US universities fulfil such functions. They introduce scientists to the business world, build networks of industrial partners, set up guidelines for the commercialisation of research findings, manage and license university owned patents, etc. Universities characterised by a larger number of staff for TTOs, higher faculty salaries and more federal and industrial resources, had a higher technology transfer effectiveness score. Although the experience with the TTOs is not always positive, certain elements are worthwhile to consider in the Dutch context. For instance, TTO-like institutions could support a more professional patent policy in the university sector. Another instrument is the Dutch TechnoPartner program, which targets at technostarters from both the public and private sector. The program emphasises the importance of science-industry interaction, and focuses on spin-offs from universities and other public research institutions.

Encourage public-private research collaborations to improve the match in research activities

Science-industry interaction will be limited when the public and the private sector have different research agendas. The match between public and private research can be improved by encouraging joint public-private research collaborations. Two important instruments in the Netherlands are the Technology Foundation STW and the Decision for Subsidies for Investments in the Knowledge Infrastructure Bsik. STW aims to finance and stimulate high-quality scientific research, and to promote the utilisation of the results of this research. The Bsik is a large scale, thematic investment in public-private research collaboration projects. Stakeholders from both the public and private sector were involved in the selection process of research themes and projects. The selection criteria refer to economic returns and scientific quality. Moreover, the Bsik requires that each research collaboration matches the Bsik subsidy by an equal amount, and that the collaboration consists of public and private partners, committing both public and private participants to the project. Some foreign policy initiatives to match the public and private research agendas are the Industry/University Cooperative Research Centers (I/UCRCs) in the US and Tekes in Finland.

Increase absorptive capacity of private firms

One way to increase a firm's absorptive capacity is to encourage R&D efforts. Policy instruments to increase private R&D investment (tax deduction programs, subsidies, or procurement) may have the side effect that absorptive capacity also increases. Previous studies on the effects of foreign and Dutch programs to stimulate private R&D activities have not paid attention to the consequences for absorptive capacity. The available studies focus on the extent to which the subsidy leads to additional R&D spending by firms (compared to a situation without the subsidy). The evidence on this so-called additionality is rather limited and mixed. The design of the R&D support program may affect science-industry interaction. First, the program may require that the R&D project entails research that is new to the market and not only new to the firm. This increases the chance that the research has close links with new scientific knowledge (although the condition may be difficult to implement). Second, the R&D program could be made contingent on the size of the firm. Small firms typically have less in-house absorptive capacity (perhaps with the exception of high-tech starters) and meet more difficulties in the capital market.

In the Netherlands, the WBSO, a wage tax credit for R&D labour, is a relatively important instrument in fostering private R&D. The WBSO in its current form is perhaps less suitable to promote absorptive capacity in the sense that the program only requires that the research to be conducted is new to the firm, not specifically new to the market. Also, the WBSO favours technostarters, which already have more intimate connections with the scientific community. On the other hand, the WBSO is more generous for small firms.

An alternative instrument which decreases the need to build absorptive capacity in-house are intermediary public research organisations such as TNO and the Great Technological Institutes (GTIs).

Be 'intelligent' with venture capital for private firms

Entrepreneurs might encounter difficulties to finance research and development projects. The TechnoPartner program includes a facility to provide certificates which can be helpful in attracting credits. While this is an interesting idea, the success or failure of such a certificate system depends on whether the financial sector accepts it or not. Anecdotal evidence suggests that banks may attach little value to such certificates. Direct public provision of capital could be an alternative, but this raises a host of other questions. It will be particularly hard to defend why the government would have more information on the prospects of a certain investment than the financial sector. Information problems can be reduced by the provision of 'intelligent' venture capital (supported by independent experts). An example is the Israeli venture capital program Yozma, and policy makers may want to consider the introduction of a similar program in the Netherlands.

Policy interventions, part II: General conclusions

The exploration of the various domestic and foreign instruments reveals that the design of an instrument determines its success, that we need to consider whether the various policy instruments reinforce or weaken each other, and that evaluation studies based on experiments should help to identify the causal impact of policy.

The design of an instrument determines its success

The review of the policy initiatives implemented in the US, Finland and Israel to remove barriers to science-industry interaction shows that the design of an instrument determines its success. For instance, the US experience with the TTOs has shown that offices with a royalty sharing system are more effective in technology transfer. Also, R&D creates not only innovations but also capacity to absorb knowledge developed elsewhere. A positive side-effect of R&D support programs is that higher private R&D activity also enables firms to make better use of the public knowledge base. These programs might be designed such that these positive side-effects of R&D are reinforced. Criteria on the innovativeness of the subsidised research and the size and nature of the firm might be considered.

Effectiveness of policy mix remains to be confirmed

In the Netherlands and other countries, a large number of initiatives to promote science-industry interaction have been undertaken, but their joint effectiveness remains to be confirmed. In particular, we need to consider whether the various policy instruments reinforce or weaken each other. At this stage, little is known about such policy interactions. As the analysis of knowledge transmission channels has shown, knowledge is often transferred through a combination of public and private channels. Therefore, in order to promote the connection with the scientific community, one could, for instance, extend the WBSO program with a facility to encourage research collaboration with the public research sector.

Experiments help to identify the causal impact of policy

Reliable ex post evaluation studies on the effectiveness of policies to encourage science-industry interaction are scarce. Insight into the effectiveness of policy could be improved by making sound ex post evaluation an integral element in the process of policy design and implementation. This requires a proper experimental design. One possibility is to use a lottery, but some form of discontinuity in the eligibility criteria can also be exploited (this is done in studies based on natural experiments). For example, the Dutch Innovation Platform randomly allocates vouchers to small and medium-sized firms. These vouchers can be used to finance research contracts with universities and non-academic research institutions. Comparison of the outcomes in the treatment group and the control group can reveal the causal impact of the innovation vouchers. Such experiments help to improve our understanding of the effectiveness of the various instruments.

1 Introduction

Economic growth is to a large extent driven by innovation, i.e. the introduction of new products, services and processes. Innovation is carried out by firms who try to distinguish themselves from their competitors. The innovation potential of firms depends on their own R&D effort and the extent to which they can benefit from the public knowledge pool. This public knowledge pool is generated by universities and publicly funded research organisations.

A widely heard concern in the member countries of the European Union is that while their universities are productive in terms of high quality scientific output, European firms make too little use of the newly created scientific knowledge. At the same time, it is believed that in the US the science-industry connections are much stronger. This so-called ‘European knowledge paradox’ is of great concern to policymakers, as limited knowledge spillovers between science and industry lower the potential for innovation and economic growth. Apparently, some barriers exist in the knowledge transfer from science to industry. Many countries have therefore undertaken initiatives to improve the university-to-industry knowledge transfer (see Chapter 2 in OECD, 2002).

The current report is about science-industry interaction in research: how to bring scientific knowledge to the market? The focus is on knowledge transfer from universities to firms.[1] The report starts by examining empirically whether the European knowledge paradox is a real problem. Second, the report discusses potential barriers to interaction on the side of the universities and the side of industry. Finally, the report investigates what kinds of policy initiatives have been taken to alleviate the various barriers, and what we can learn from these experiences.

In Chapter 2, we present some indicators on knowledge utilisation and interactions between science and industry in order to try and quantify the European paradox, and its importance for macro-economic performance. We also look at the various channels of knowledge transfer between science and industry. These channels include publications, patents, consulting, informal meetings, recruiting, licensing, joint ventures, research contracts, etc. Insight into the quantitative importance of the various transmission channels will help to design appropriate policy instruments. The analysis shows that the evidence on the European knowledge paradox is mixed and incomplete, and that public channels of knowledge transfer in conjunction with personal contacts are essential.

Chapters 3 and 4 elaborate on potential barriers within the public research sector and within firms. These potential barriers are identified by studying certain characteristics of the universities and firms as described in the economic literature. An important element is the incentive structure. Within the university sector, one important incentive concerns the reward of

[1] In this report, the Dutch upper vocational education (HBO) institutions and the publicly funded non-academic research institutions are considered as a means to bridge the gap between science and industry (see Chapter 6).

scientists for commercialisation of their ideas (Chapter 3). And what is the price of intensified relationships with industry in terms of the disclosure of research findings, or change in the nature of research? Chapter 3 also discusses some other potential barriers within the public research sector. For firms, in order to benefit from knowledge spillovers, it is important to build 'absorptive capacity' (Chapter 4). A firm's R&D effort increases innovation, but it also helps to make use of the public knowledge pool. The adoption of scientific knowledge by firms may also be affected by information problems. Such information asymmetries could lead to credit market problems, making it difficult for firms to finance R&D activities. Chapter 4 deals in greater detail with these issues. The focus of the current report is on the utilisation of public knowledge, but we emphasise that there is strong evidence for reverse knowledge spillovers, and university-industry interaction can be fruitful for academics in terms of new ideas.

In Chapter 5 and 6, we explore a number of international and national policy initiatives aimed at promoting university-industry knowledge spillovers. Unfortunately, convincing evaluation studies are scarce, making it difficult to assess the effectiveness and efficiency of the various policies. We will however try to analyse whether the different policies are expected to be able to alleviate the barrier for science-industry interaction for which they are designed in the first place. It appears that the design of instruments and the policy mix of instruments are important elements in the success of policy initiatives. Evaluation studies based on experiments should help to identify the causal impact of policy.

Chapter 7 sums up the evidence and derives some general policy options.

2 Science-industry interaction: An empirical assessment

How important are science-industry interactions in research for economic growth? Which transmission channels are important? Is there really a European knowledge paradox? The current chapter presents some empirical evidence on science-industry interaction. Strong correlations are found between the intensity of university/industry research collaboration and a number of indicators for the knowledge economy, such as R&D investments, the quality of research institutions and public support for private R&D. Furthermore, transfer channels which are accessible to everyone, such as publications and meetings, appear to be relatively important. But they go in conjunction with channels where personal contacts are essential, such as consulting. Finally, a comparison across a selection of OECD countries reveals that it is probably an overstatement to talk of a European knowledge paradox, although the United States seems to show a somewhat better performance. Relatively weak points in the Netherlands compared to other European countries are the cooperation between national universities and the private sector, and the importance of universities as a source of knowledge for the service sector.

2.1 Introduction

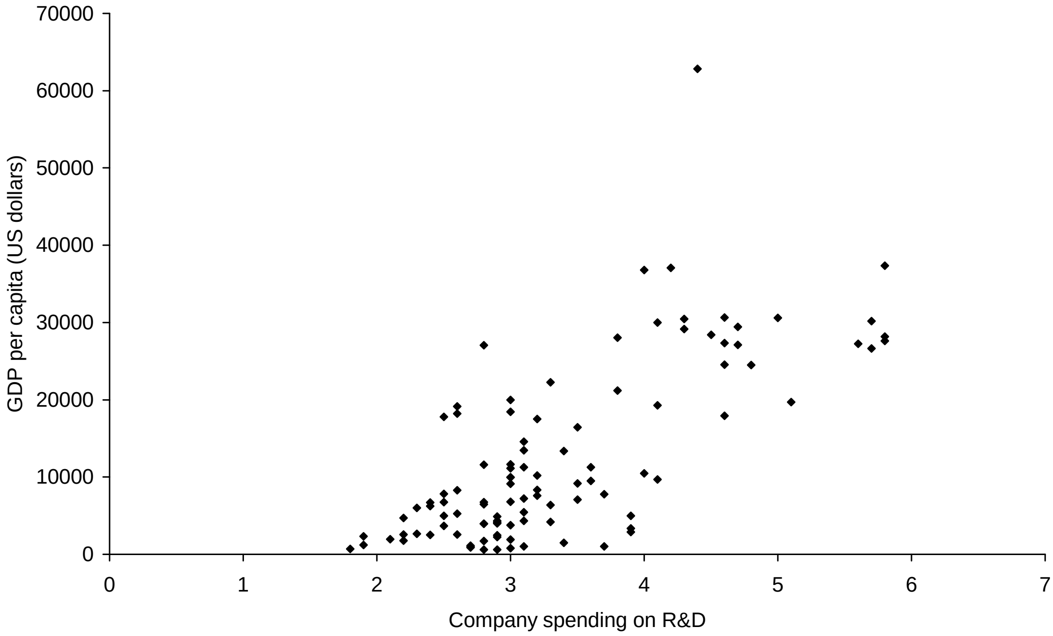
It is widely believed that knowledge transfer from science to industry is important for a strong performance of the economy. This is accompanied by a policy concern within the European Union about the so-called European knowledge paradox, which states that European firms utilise relatively less scientific knowledge from universities compared to their American counterparts. But do the facts confirm these policy views? The current chapter investigates the empirical relationship between science-industry interaction and macro-economic performance (Section 2.2). The latter is the subject of ongoing concern for the government. Second, some evidence is presented on the various types of connections (i.e. transmission channels) between science and industry (Section 2.3). Insight into the quantitative importance of transmission channels may help to design policy instruments. Finally, the chapter explores indicators on science-industry interaction for the European Union compared to the United States, with a focus on the Netherlands (Section 2.4). Is the US performance with regard to science-industry interaction better than in the EU-countries?

2.2 Science-industry interaction, R&D and macro-economic performance

How important is science-industry interaction in research for macro-economic performance? Theoretically, this relationship runs via private R&D activity. Figure 2.1 presents the correlation between per capita GDP and R&D conducted by the private sector for 104 countries in 2004, based on data provided by the World Economic Forum (2004) in the Global

Competitiveness Report 2004-2005.[2] These 104 countries cover 98% of the world's GDP. The figure shows a positive relationship between company R&D spending and per capita GDP, although there is substantial dispersion in the data.[3] Though no causal relationships are presupposed in the current exercise,[4] it should be noted that the correlation between R&D and per capita incomes can be blurred because several potentially important explanatory variables are omitted, such as investments in physical and human capital. But the overall picture is consistent with the widely supported view that R&D generates substantial returns.

Figure 2.1 Correlation between company R&D spending and GDP per capita for 104 countries, 2004



Note: Company R&D spending is measured by a scale factor based on the question "Companies in your country (1=do not spend money on research and development, 7=spend heavily on research and development relative to international peers)". Source: World Economic Forum (2004), Global Competitiveness Report 2004-2005, international survey among business executives and entrepreneurs.

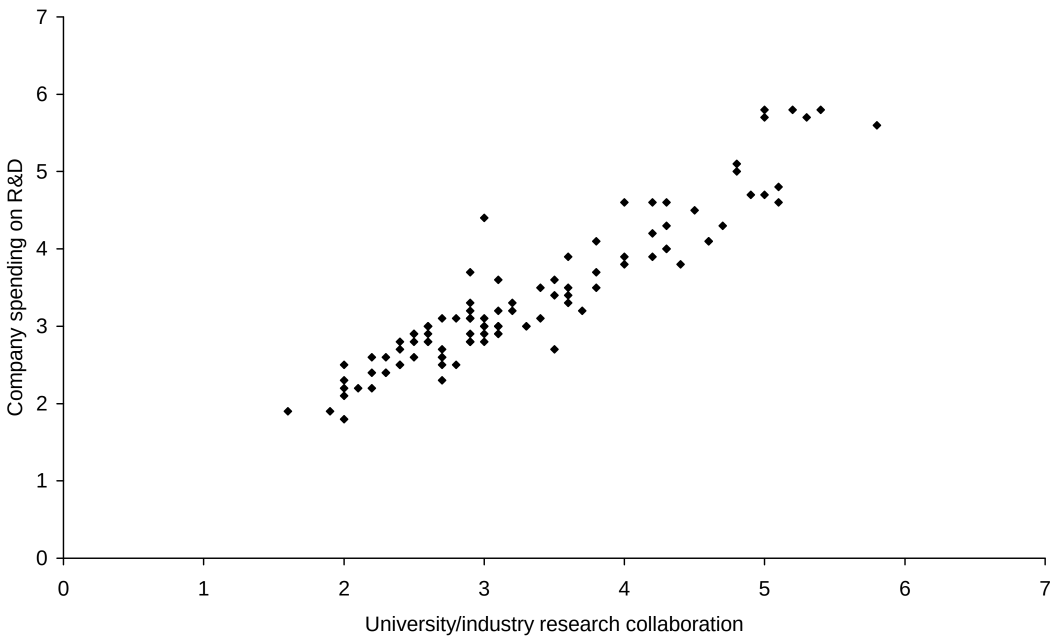
[2] It would be preferable to use data on labour productivity, as employment and hours worked per person differ substantially across countries. However, such data are not readily available for a large group of countries. The R&D data are from a large-scale international survey among business executives and entrepreneurs (8,729 responses from 104 countries). Company R&D spending is measured by a scale factor based on the statement "Companies in your country (1=do not spend money on research and development, 7=spend heavily on research and development relative to international peers)". Survey data may be unreliable when 'optimism' or 'pessimism' is correlated among individuals in one country, or when the law of large numbers does not apply (i.e. when there is only a limited number of respondents) so that individual idiosyncratic errors do not wash out in the country average. But the survey data on R&D show a fairly large correlation with 'hard' macro-economic data on R&D/GDP-ratios reported by the OECD Main Science and Technology Indicators (R^2=0.73 for 37 countries). Two outliers (with the highest R&D/GDP-ratios) are Sweden and Israel, where executives and entrepreneurs seem to underestimate the total private R&D performance of their country.

[3] The outlier in per capita GDP around US $ 63,000 is Luxembourg.

[4] To identify causality, purely exogenous variation in the independent variables is required, and such an econometric investigation is beyond the scope of this study.

We expect private R&D activity to be related with a large range of factors, among which the interaction between science and industry. The World Economic Forum (2004) provides country data on university/industry research collaboration within a country, with the scale measure: "In its R&D activity, business collaboration with local universities is (1=minimal or nonexistent, 7=intensive and ongoing)". Figure 2.2 shows the relationship between the intensity of science-industry research collaboration and company spending on R&D. Without claiming causality, the figure clearly shows that countries where the respondents indicate that companies spend heavily on R&D also tend to be countries with intensive and ongoing research collaboration between the private sector and local universities. Several studies on micro-level data for specific countries (Belderbos et al. (2004) for the Netherlands, Faems et al. (2005) for Belgium, Lööf and Heshmati (2002) for Sweden) also find that university/industry research collaboration is one of the central building blocks of a national innovation system.

Figure 2.2 Correlation between university/industry research collaboration and company R&D spending for 104 countries, 2004



Note: The intensity of university/industry research collaboration is scaled 1 to 7 based on the statement "In its R&D activity, business collaboration with local universities is (1=minimal or nonexistent, 7=intensive and ongoing)". Company R&D spending is measured by a scale factor based on the question "Companies in your country (1=do not spend money on research and development, 7=spend heavily on research and development relative to international peers)".
Source: World Economic Forum (2004), Global Competitiveness Report 2004-2005, international survey among business executives and entrepreneurs.

It should be stressed that these observed correlations do not allow us to draw inferences about causality. Intensive science-industry interaction could encourage private R&D investments, but it could also work the other way: companies heavily investing in R&D seek for research collaboration with the public sector. This is important, as it implies that policies to strengthen science-industry interactions may not be effective when causality runs the other way. In that case, more intensified R&D collaborations would be a side-effect of policies to encourage private R&D investments. Further research should improve our understanding on the causal impact of science-industry interaction.

The intensity of university/industry collaboration might be related to other factors. For instance, the quality of education and public research institutions, the availability of scientists and engineers and patenting by universities may provide incentives for transfer of scientific knowledge from the public research sector. Furthermore, the utilisation of scientific knowledge by business firms may be boosted by the eagerness of firms to absorb new technologies, venture capital availability, subsidies and tax credits for firm-level research and development, and more generally, the tax burden and the intensity of local competition.

On the basis of data provided by the World Economic Forum (2004), it appears that intensity of university/industry collaboration correlates strongly with such factors, in particular the quality of scientific research institutions, intellectual property protection, public support for private R&D, and the availability of venture capital (Table 2.1), again without presupposing causal relationships.[5]

Table 2.1 Correlations between company R&D spending, university/industry collaboration and other factors across 104 countries, 2004

	R&D	COLL	QINST	ENGIN	QM&S	IPR	ABS	VC	SUB	TAX	COMP
R&D	1.00										
COLL	0.94	1.00									
QINST	0.91	0.90	1.00								
ENGIN	0.66	0.67	0.75	1.00							
QM&S	0.62	0.65	0.69	0.80	1.00						
IPR	0.84	0.84	0.80	0.61	0.62	1.00					
ABS	0.80	0.78	0.76	0.67	0.58	0.82	1.00				
VC	0.78	0.81	0.78	0.62	0.63	0.84	0.76	1.00			
SUB	0.79	0.83	0.78	0.66	0.69	0.76	0.71	0.74	1.00		
TAX	– 0.01	– 0.09	0.04	– 0.07	– 0.17	– 0.15	– 0.28	– 0.24	– 0.09	1.00	
COMP	0.71	0.75	0.74	0.62	0.60	0.74	0.78	0.75	0.69	– 0.15	1.00

Note: R&D = company R&D spending; COLL = university/industry collaboration; QINST = quality of research institutions; ENGIN = availability of scientists and engineers; QM&S = quality of math and science education; IPR = intellectual property protection; ABS = firm-level technology absorption; VC = venture capital; SUB = public support for private R&D; TAX = tax burden; COMP = intensity of local competition. Correlations are calculated on basis of scale factors.
Source: World Economic Forum (2004), Global Competitiveness Report 2004-2005, international survey among business executives and entrepreneurs.

[5] All variables are measured on a scale, from 1 (low, small, or weak) to 7 (high, large, or strong). 'Intellectual property protection' concerns also patenting by private firms (and other forms of intellectual property protection), not only university patenting (which is actually only a small fraction of total patenting).

In the perception of business executives and entrepreneurs, countries differ substantially in R&D performance, university/industry collaboration and the other related factors (Table 2.2). The US appear most often in the top 3. In Europe, the most advanced countries are Sweden and Finland. For the rest of the world, Singapore and Israel are prominently present in the top 3. Finland is on top when it comes to managers' satisfaction with university/industry collaboration, while the Netherlands shows up at the seventh place. In terms of intellectual property protection and venture capital availability, the Netherlands scores highly with a fourth position. The quality of Dutch research institutions is in the upper bound, with the Netherlands ranking seventh (and the US first). Regarding public support for private R&D via subsidies and tax credits, the Netherlands appears at the ninth place.

Low rankings might indicate potential barriers in science-industry interaction in the countries under consideration. However, this is a rather rough indication. First, the differences between the scores of many countries are very small. This implies that rankings may change easily across years without a fundamental shift in comparative economic performance. Second, the variables do not tell much about science-industry interaction via different channels and at a more disaggregated level. Section 2.3 and 2.4 provide more detailed evidence on these issues.

Table 2.2 Summary statistics on company R&D spending, university/industry collaboration and other factors across 104 countries, 2004

Variable	Mean	St. dev.	Min.	Max.	Top 3			Dutch ranking (score)
R&D	3.37	0.94	1.8	5.8	Jap	US	Ger	7 (4.7)
University/industry collaboration	3.30	0.95	1.6	5.8	Fin	US	Swe	7 (4.9)
Quality research institutions	3.96	0.95	2.1	6.3	US	Swe	Isr	7 (5.4)
Scientists and engineers	4.65	0.91	2.0	6.3	Ind	Fin	Isr	14 (5.0)
Quality of math and science education	4.12	1.08	1.8	6.2	Sgp	Fin	Fra	10 (5.1)
Intellectual property protection	3.86	1.26	1.8	6.3	Swe	Den	US	4 (6.0)
Firm-level technology absorption	4.59	0.90	2.6	6.3	Jap	US	Swe	13 (5.0)
Venture capital	3.30	0.91	1.4	5.8	US	Isr	UK	4 (4.9)
Public support for private R&D	3.13	1.02	1.5	5.5	Sgp	Lux	Tai	9 (4.4)
Tax burden	3.63	0.64	1.5	4.8	Bah	UAE	Sgp	14 (3.7)
Competition	4.76	0.68	2.8	6.3	US	UK	Aus	5 (5.7)

Note: Dutch ranking calculated by giving countries with similar scores the same position in the ranking (i.e. by deleting multiple counts).
Source: World Economic Forum (2004), Global Competitiveness Report 2004-2005, international survey among business executives and entrepreneurs.

2.3 Channels for knowledge transfer from science to industry

Which types of knowledge transfer channels between science and industry do exist and which ones are relatively important? Several transmission channels can be identified, such as:

- Scientific publications: By publishing the results from their research, academic scientists make new scientific knowledge widely available to the community and business.
- Outsourcing of research by firms: Firms can decide to (partially) outsource their research activities to a university or public research institute.
- Start-ups: Academic researchers and students can decide to start their own company and bring a new idea to the market.
- Patents and licensing: Protection of intellectual property on academic research results should help to promote knowledge diffusion to industry.
- Human capital mobility: Human beings are the carriers of tacit knowledge, so a direct way for firms to gain access to tacit knowledge is to hire students and university staff. Also more temporary forms of human capital mobility, such as internships and consulting services, can contribute to science-to-industry knowledge transmission.

The extent to which knowledge is tacit is an important element in the transmission of knowledge from science to industry. New knowledge is developed in tacit form, i.e. in its inventor's head. Cowan and Foray define knowledge codification as "the process of conversion of knowledge into messages which can be processed as information" (p. 2, 1997). Tacit knowledge can only be transmitted through social interaction between the sender and the recipient, while the transfer of codified knowledge does not require personal contact. Tacit knowledge thus possesses characteristics of a 'normal' economic commodity in the sense that it is rival and excludable (and thus tradable on markets).

However, this does not imply that no market failures arise in the transfer of tacit knowledge. The public good character of academic research should guarantee optimal spillovers to the business community. The open science culture of universities encourages scientists to codify their research findings, e.g. in the form of publications. When a scientific discovery is published in a journal, the market sector has access to the idea and can decide whether or not to commercialise it. However, even though good journals demand that the results are reproducible, it is often impossible or too costly to codify all knowledge and part of it will remain tacit. In that case, publication of research results is not sufficient to bring scientific discoveries to the market. Other transmission channels with more personal contacts (such as consulting services) are then needed.

An implication of the fact that knowledge remains partly tacit is that spillovers will be bounded geographically. In fact, several authors found that spillovers from academic research are more localised than spillovers from industrial research. For instance, Frenken and Van Oort

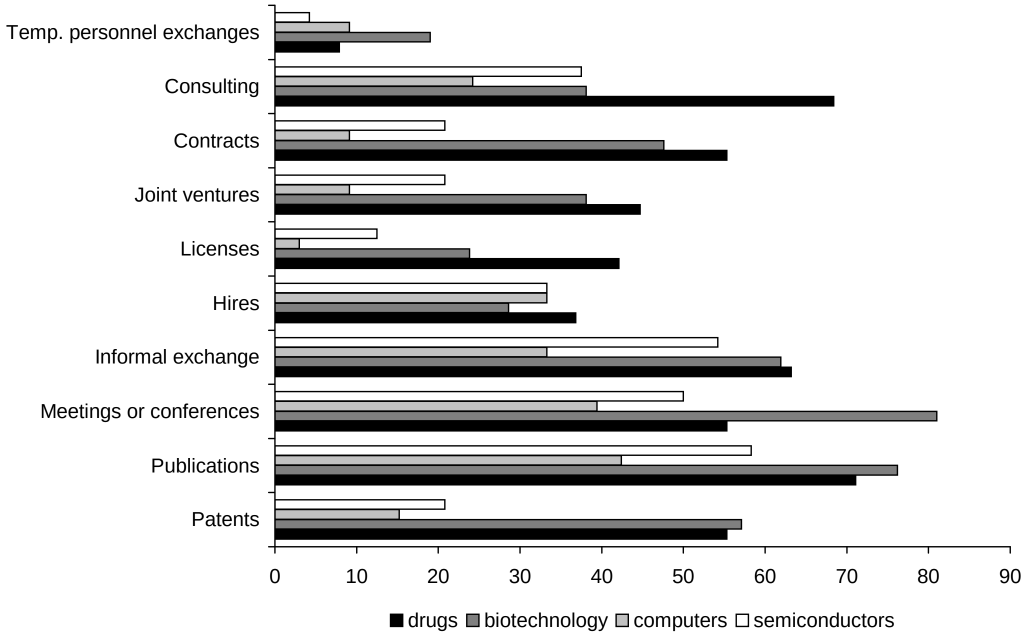
(2004) study the role of proximity in scientific collaboration in biotechnology and applied microbiology. The authors use data from the Institute of Scientific Information, and study collaboration among research institutions in the US and the European Union. Frenken and Van Oort find that ‘hybrid’ collaborations, i.e. collaborations between an academic and a non-academic organisation, are characterised by a higher degree of geographical localisation than other types of collaboration. Adams (2002, p.2) argues that “Since academic research is usually regarded as more of a public good than firm research, this finding poses something of a puzzle. The solution requires one to see that geographic localization of university spillovers reflect ease of dissemination of normal science, which takes place through nearby institutions”.[6]

Cohen and Walsh (2000) consider the transmission channels through which public research affects industrial R&D for four industries (drugs, biotechnology, semiconductors and computers). They “… hope to arrive at some idea of the extent to which firms might rely on channels of information from public research institutions that are public, private or lend themselves to privatization” (p. 6, 2000).[7] The authors use the 1994 Carnegie Mellon Survey to investigate these transmission channels.[8] The respondents were asked on a four point Likert scale to report the importance to a recently completed major R&D project of each of ten possible sources of information, i.e. patents, publications and reports, meetings or conferences, informal exchange, hires, licenses, joint ventures, contracts, consulting, and temporary personnel exchanges. Figure 2.3 shows the percentage of respondents reporting that a given source was at least ‘moderately important’ (i.e. scale 3 or 4). The most important transmission channels in the four investigated industries appear to be the ‘public’ ones, namely publications and reports, and meetings or conferences.

These results are similar to findings for the manufacturing sector as a whole as presented in Cohen et al. (1998). This latter study reports as the four dominant transmission channels (in descending order of importance) publications and reports, public meetings and conferences, informal information channels, and consulting. Cohen et al. (1998) also conduct a factor analysis, and find that the four transmission channels tend to be used together. This is important, as it suggests that person-to-person interactions tend to be used in conjunction with more public channels. This supports the idea that tacit and codified knowledge are complements in the knowledge transfer process.

[6] This spatial proximity may also affect the issue of university financing. Local governments should consider the role of their universities in regional economic development when spillovers are localised (cf. Varga, 1997). The financing of research activities with global spillovers should be a matter of concern at the national and international level.
[7] Here the term ‘public’ refers to the openness of the channel, the extent to which it is accessible to everyone, in contrast to ‘private’ information channels. They do not refer to the distinction between government and business.
[8] This survey is held among R&D managers. The survey data yielded 40 observations in the drug industry sample, 21 in biotechnology, 25 in semiconductors, and 34 in computers.

Figure 2.3 **Channels of knowledge transmission (% of respondents reporting that a given source is at least 'moderately important')**



Source: Cohen and Walsh (2000).

2.4 Is there a European knowledge paradox?

Are the policy concerns about a European knowledge paradox justified? This section explores a number of indicators to get an idea of relative strengths and weaknesses of science-industry knowledge spillovers in the EU compared to the US, with a focus on the Netherlands.

Table 2.3 shows the ranking of the Netherlands compared to a selection of countries in 2000 or 2001 on a set of knowledge transfer indicators (based on Antenbrink et al., 2005). Antenbrink et al. (2005) conclude that the Netherlands does not perform systematically better or worse in science-industry interaction than the US, Sweden or Finland. The picture of interaction between science and business is mixed, as the ranking of the countries varies strongly across indicators. Moreover, indicators are lacking for a number of important channels of interaction (particularly for the US), such as personnel mobility.[9] On three out of six indicators for which data about the US are available, the country ranks first. But it seems to be an overstatement to use this as evidence for the existence of a European knowledge paradox.[10] Dosi et al. (p.2,

[9] Zucker et al. (1997) study the role of labour mobility in the transmission of knowledge from science to industry in the US bioscience and related biotechnology industries. In particular, their idea is that scientific knowledge with natural excludability (say, tacit knowledge) may be best transferred to industry by the labour mobility of top scientists ('star scientists') from universities and research organisations to firms. This labour mobility can take the form of a change in employment, or some kind of collaboration on joint research projects or patenting. Zucker et al. find that star scientists are likely to move at least some of their labour from universities to firms. The valuable intellectual human capital captured in the top scientist is a key determinant of mobility. Another example is Kim et al. (2005).

[10] A discussion on the robustness of these indicators is provided in Antenbrink et al. (2005).

2005) put it as follows: “we soon realized [...] that the paradox mostly appears just in the flourishing business of reporting to and by the European Commission itself rather than in the data”.

A relatively strong point of Dutch science-industry interaction seems to be the financing of public research by Dutch firms, particularly the financing of non-academic institutions.[11] Compared to the US, Sweden and Finland, this source of financing is relatively important in the Netherlands. The number of patents,[12] licenses and spin-offs is also relatively large, and comparable to the US. Measured by co-publications,[13] there is also relatively much interaction, comparable to the US and Sweden. The international business sector quotes Dutch scientific research relatively often.[14] The US and Sweden are only slightly ahead of the Netherlands.

But in formal cooperation the Netherlands scores relatively low, particularly in the cooperation of firms with national universities. Sweden and Finland perform better in this respect. In addition, universities and other research institutions are not often mentioned as an important knowledge source for Dutch firms. Only for firms in the service sector, the non-academic institutions are relatively important. Utilisation of these knowledge sources for Finnish and Swedish firms varies strongly by sector and type of institution.

The rankings in Table 2.3 do not reveal how important the different channels are compared to each other. Table 2.4 provides some evidence on the relative importance of various information sources for innovative firms in a selection of EU countries, from the Third Community Innovation Survey (CIS-3). The table shows that the dominant information sources for firms refer to internal and market sources. Universities and other research institutions are substantially less often ‘very important’ sources of information, and cross-country differences seem rather small. Universities in the Netherlands are less often mentioned as an important information source compared to the EU-average. Notice that also in Finland, often mentioned as a successful country when it comes to the importance of universities for the private sector, only 3% of the innovative firms report universities or other higher education institutes as a very important information source, and this is only one percentage point higher than the Netherlands. For some other sources (professional conferences and publications, fairs and exhibitions), rather substantial cross-country differences are observed.

[11] The idea here is that firms are mainly interested in contributing to scientific research when this is expected to generate usable results. But firms paying for research in the public sector often demand some exclusiveness on the results (e.g. secrecy or intellectual property rights), which actually may hamper knowledge transfer to other firms (Pomp, 2003).

[12] Verspagen (2004) argues that official statistics tend to underestimate the patenting activity of Dutch universities, due to definition issues (cf. Chapter 6).

[13] Co-publications have at least one author from the private sector and one author affiliated with a university.

[14] A comparable indicator is citations to scientific research in patents of firms. Pomp (2003) uses the average number of references in US patents by patent holders in country X to scientific publications from country X per 100 publications during the period 1990-1997. The Dutch score is about 0.27, implying that about 370 (100/0.27) scientific publications are needed to produce one reference in a US patent of a Dutch firm. This is large compared to other countries (Finland, Australia, Sweden, UK, Canada). The US is far ahead of all other countries.

Table 2.3 Summary of rankings on knowledge transfer indicators within a selection of countries

	NL	US	Fin	Swe	Bel	Ger	UK
Research at other public research organisations financed by the private sector[a]	1		2	6	3	5	4
Number of licenses per 1000 scientists in the public research sector[b]	2	1			4	3	
Number of spin-offs per 1000 scientists in the public research sector[b]	2	1			3	4	
Co-publications as % of total publication-output[c]	2	4	6	3	1	7	5
Other public research organisations as very important source of knowledge, services[d]	2		4	1	6	3	5
Cooperation with other public research organisations, services[d]	2		1	3	5	4	
Number of patents per 1000 scientists in the public research sector[b]	3	1			4	2	
Research at universities financed by the private sector[a]	3	7	4	6	1	2	5
Cooperation with other public research organisations, industry[d]	3		1	2	4	5	
Citations to scientific research in publications of international business sector[c]	4	1	7	3	2	6	5
Universities as very important source of knowledge, industry[d]	4		5	3	2	1	6
Other public research organisations as very important source of knowledge, industry[d]	4		1	5	2	3	6
Cooperation with national universities, industry[d]	5		1	2	3	4	
Cooperation with national universities, services[d]	5		1	2	3	4	
Universities as very important source of knowledge, services[d]	6		4	1	3	2	5

Source: Antenbrink et al. (2005).
[a] Data from OECD, rankings in 2001.
[b] Data from OECD, rankings in 2000-2001.
[c] Data from NOWT, rankings in 2001.
[d] Data from Eurostat and CIS, rankings in 2000.

It should be noted that these results are not directly comparable to those reported by Cohen and Walsh (2000). Percentages refer to firms reporting a source as ‘very important’ (comparable to the highest score on a four point Likert scale). Unfortunately, no distinction is made between professional conferences and publications. The outcomes of the earlier Second Community Innovation Survey (CIS-2) on the years 1996-1997 suggest that codified information sources such as computer-based information networks and patent disclosure are only for few firms a very important source of information (OECD, 1999).[15]

Brusoni et al. (2002) use CIS-data to further explore how important codified information sources are for innovation in the Netherlands. As the survey combines publications and conferences within the same category, while only the former can be considered as a codified source of information, Brusoni et al. cannot use responses to this question in their analysis. Instead, they construct a proxy for the importance of codified knowledge based on ‘computer-based information networks’ and ‘patent disclosures’. Codification is strongest in science-based sectors, such as chemicals and electrical and optical equipment. There are strong differences in the use of codified sources across sectors, and at the other end of the spectrum we find sectors like food and textiles and leather where the codification index is relatively low. The codification variable is used in a firm-level regression analysis. Results show that the use of other (more tacit) information sources is an important explanation for the use of codified sources by individual firms. Brusoni et al. call this link between the use of codified and other sources of information the ‘embeddedness effect’. Codified information sources and other sources are

[15] In the CIS-3, these information sources are not included any more.

complements. This finding is in line with the results in Cohen et al. (1998) for the US discussed above.

Table 2.4 Percentage of innovative firms reporting that a given source is 'very important', 1998-2000

	NL	Bel	Fin	Ger	Swe	UK	EU
Internal sources							
Within the enterprise	51	51	45	39	50	41	38
Other enterprises within the enterprise group	12	17	12	11	16	11	9
Market sources							
Suppliers of equipment, materials, components, software	12	27	10	19	21	23	20
Clients or customers	17	28	26	41	48	21	28
Competitors & other enterprises from same industry	7	12	4	17	11	7	12
Institutional sources							
Universities or other higher education institutes	2	5	3	8	7	2	5
Government or private non-profit research institutes	3	2	4	3	3	1	3
Other sources							
Professional conferences, meetings, journals	5	10	2	20	3		11
Fairs, exhibitions	6	15	5	24	7		16

Source: CIS-3, Eurostat (2004).

Does the importance of certain sources of information depend on firm-size? Table 2.5 presents the importance of sources of information for small, medium-sized, and large companies in the EU. The larger the innovating company, the higher the probability that in-house sources dominate. Interestingly, not-for-profit research institutes are mentioned more often as an important information source for innovation by large companies. Also, large companies with innovation activity show a greater propensity to collaborate with universities or other higher education institutes, and seem to be more active in networks (conferences, meetings, and journals) than small and medium-sized firms. According to Eurostat (p. 45, 2004), this suggests that "economies of scale could be an important factor in determining whether or not an enterprise has the resources to follow-up on potential sources of information for innovation". An alternative explanation is the role of absorptive capacity: large firms who are more likely to do R&D in-house are better able to exploit knowledge developed in the academic community. The concept of absorptive capacity is discussed in Chapter 4.

A final issue is whether the importance of certain sources of information depends on the sector under consideration. In Table 2.6 Dutch companies are divided by firm size and sector (industry, manufacturing, and services). In all three sectors, information sources within the enterprise are the most important, and their importance increases with firm size. At the sector level it is interesting to notice that large firms in industry and manufacturing cite the non-academic research sector more often as important than SMEs, while large and medium-sized firms in the service sector seem less inclined to utilise information from non-profit research organisations than small companies. Perhaps the notion of absorptive capacity is more relevant for industry and manufacturing, so that large firms with in-house research programs are more strongly connected to the public research community.[16]

Table 2.5 Percentage of innovative firms reporting that a given source is 'very important', by firm size, 1998-2000

	Total	Small	Medium	Large
Internal sources				
Within the enterprise	38	34	41	70
Other enterprises within the enterprise group	9	6	14	31
Market sources				
Suppliers of equipment, materials, components, software	20	19	18	29
Clients or customers	28	26	30	47
Competitors & other enterprises from same industry	12	11	13	21
Institutional sources				
Universities or other higher education institutes	5	4	5	10
Government or private non-profit research institutes	3	2	3	6
Other sources				
Professional conferences, meetings, journals	11	11	10	16
Fairs, exhibitions	16	16	15	17

Note: Small firms refer to firms with 10 to 49 employees; medium-sized firms refer to firms with 50 to 249 employees; large firms refer to firms with 250 or more employees.
Source: CIS-3, Eurostat (2004).

Table 2.6 Percentage of innovative firms reporting that a given source is 'very important', by sector and firm size, 1998-2000

	Total			Industry			Manufacturing			Services		
	S	M	L	S	M	L	S	M	L	S	M	L
Internal sources												
Within the enterprise	50	52	57	52	53	56	52	53	57	47	52	58
Other enterprises within the enterprise group	9	15	19	5	12	19	5	12	20	13	21	20
Market sources												
Suppliers of equipment, materials, components, software	13	10	8	14	8	8	13	8	8	12	12	8
Clients or customers	17	18	16	18	19	19	18	19	20	15	17	11
Competitors & other enterprises from same industry	7	7	7	9	7	8	9	7	9	4	7	5
Institutional sources												
Universities/other higher education institutes	2	3	3	3	2	4	3	2	4	1	4	1
Government/ PNP research institutes	3	2	4	2	1	6	2	2	6	4	2	2
Other sources												
Professional conferences, meetings, journals	6	4	4	6	3	6	6	3	4	5	5	1
Fairs, exhibitions	7	4	2	8	4	3	8	4	3	6	3	1

Note: S = small firms (10 to 49 employees); M = medium-sized firms (50 to 249 employees); L = large firms (250 or more employees).
Source: CIS-3, Eurostat (2004).

[16] A more elaborate discussion of the relationship between firm size and absorptive capacity in the Dutch context can be found in AWT (2003).

3 Potential barriers within the public research sector

Which elements of the internal structure of universities and other public research organisations form a potential barrier to effective knowledge transfer? The current chapter identifies three potential barriers. The most essential barrier is probably that academic scientists are usually rewarded on the basis of their publication record, while firms would like to keep particular results from scientific research secret. A second barrier is the involvement of public sector researchers in commercialisation of scientific research results is limited, as this is considered to be outside the scope of an academic. Third, research agendas in the public and private sector are different, which might decrease the potential for mutual interaction. Potential disadvantages of stronger links with the business sector, i.e. problems with the disclosure of research results and shifts in the agenda away from fundamental to more applied research, do not receive strong empirical support.

3.1 Introduction

Several potential barriers connected to the internal structure of universities may prevent an effective knowledge transfer. From an inspection of the literature, we identify three potential barriers:

1. The reward structure of academic scientists
2. The lack of entrepreneurial culture
3. The determination of the research agenda

The reward structure seems the most important barrier for universities to knowledge transfer. Academic scientists are usually rewarded on the basis of their publication record, while firms would like to keep particular results from scientific research secret. Entrepreneurial activities by scientists will also be related to this reward structure, and the problem of diverging research agendas in the public and private domain can be reduced by making it attractive for scientists to collaborate with industry. For each of these factors, we now explore how the current structure in place may hinder university-to-industry knowledge transfer. We also discuss whether stronger ties between academics and the business sector pose a threat in the form of a trade-off between science and commerce in publicly performed research.[17]

[17] The current chapter focuses on universities, as they are the primary producers of scientific knowledge. The three potential barriers for science-industry interaction identified in this chapter will also play a role for the other higher education institutions such as professional higher education (e.g. the Dutch HBO-institutions) and non-academic public research institutions.

3.2 Reward structure of academic scientists

Academic scientists are usually rewarded on the basis of their publication record, while firms would like to keep particular results from scientific research secret. Particularly the scientifically ambitious universities have a 'publish-or-perish' culture. Publication of research results implies disclosure of knowledge, and this clashes with the norm of secrecy common within the business world (Dasgupta and David, 1994). But even without such a cultural clash it is safe to state that scientists experience little or no incentives to engage in science-industry interaction, while they experience high-powered incentives to publish. Specifically, academic employees are rewarded for their efforts with regard to education and research, but there is generally no specific reward for activities related to science-industry interaction (this at least holds for the Netherlands). Firms require secrecy to protect their ideas from potential competitors. An academic researcher may not want to work together with industry if this cooperation implies that his results cannot be published. Likewise, a research department of a commercial firm may be reluctant to collaborate with researchers working in the public sector if that would endanger secret projects to the benefit of its competitors. The Box discusses some economic theory on the reward structure of public sector researchers.

Rewarding academic scientists: A principal-agent problem for the university administration

Economic theory studies the design of the reward structure within universities as a typical principal-agent problem (Dasgupta and David, 1994). The 'principal', i.e. the university administration, cannot fully observe the effort engaged in research activities by the 'agent', i.e. the scientist. Therefore, to solve the moral hazard problem, pay must be based on some sort of observable output or achievement. Scientific output is typically measured by the number of publications, weighted (in some way) by quality. Publishing in prestigious journals is a sign of outstanding performance, which translates in higher rewards for the scientist. These rewards generally take the form of indirect (or future) benefits, like promotions (Diamond, 1986).

The particularity of science, however, is that it pays to be first, but it does not pay to be second or third. Only novel ideas are published, since the replication of ideas is useless for the advancement of science. This 'rule of priority' implies that a reward structure based only on publication counts would be very risky for the scientists. No scientist would want to engage in science if only the 'winner takes it all'.[a] Of course, in reality scientists may operate in a less risky environment. The point here is that due to the inherent risks involved in research activities, high-powered incentives are not appropriate, and scientists should also receive a fixed salary which is not dependent on performance.[b] Hence, academics are partly insulated from the risk associated with research through weak direct financial incentives and the tenure system.

[a] It should be noted that the winner takes it all argument can also induce more investments in basic research, for instance in the private sector. The firm who is the first to acquire the knowledge obtains the full market profits, or at least a very considerable share of it. In that case, Dasgupta and Maskin (1987, p. 594) conclude that because firms aim to be the first to innovate "in a large class of cases, [the market] induces excessively risky projects."

[b] Another reason why one should be careful with the use of high-powered incentive schemes for scientists is crowding-out of intrinsic motivation (see e.g. Canton, 2005).

A final issue is that even if academic scientists and business firms do not cooperate in research, one would expect that firms should nevertheless greatly benefit from the open science culture within universities. Results from academic research become readily available to firms when they are published. However, publications can only contain the codified part of the newly generated knowledge. As tacit knowledge needed to fully understand the scientific idea is much harder to transfer. This connection between tacit and codified knowledge leads to local knowledge spillovers. The literature studying the channels of knowledge transfer between universities and firms indeed finds that local spillovers seem to play a more important role than spillovers through publications (Mansfield, 1995; Jaffe, 1989; Adams, 2002). In other words, proximity and direct contacts are often more valuable to firms than publications.[18] This means that science-industry interaction could be hampered when academic scientists are mainly rewarded for their performance measured by publications. Without personal interaction with scientists, many firms will not be able to utilise academic knowledge.

3.3 Lack of entrepreneurial culture

A second potential barrier to effective knowledge transfer is that academics lack entrepreneurial spirit in the sense of commercialisation of scientific research results (such as starting a firm), as this is considered to be outside the scope of an academic. Due to the importance of tacit knowledge, the inventor is actually the most able to reproduce his own work, and to derive further commercial applications from his idea. But university researchers often stop at the 'proof of principle' stage and do not make the last step of commercialising their ideas. One reason for this could be that it is rather a long way from the original abstract idea into a prototype product, but another explanation is that the culture within universities often discriminates against scientists with an entrepreneurial orientation.

The academic culture follows from the view of what many universities consider as their main task: conducting fundamental research for the benefit of society. In their study of entrepreneurial behaviour in life sciences, Louis et al. (p. 110, 1989) note that "there is a tendency to distinguish between the search for truth in science, considered as a legitimate function of the university, and the search for invention, which is considered an inappropriate focus on ideas that have potential commercial or practical applicability."

The lack of entrepreneurial culture has several consequences. Scientists, who almost all lack prior business experience, are often not aware that commercialisation is possible, and how they can commercialise their knowledge. They do not know the market and potential niches on this market. For most scientists, it is impossible to develop an important network with the key actors in the business world. Even if scientists were aware of market opportunities, they would meet difficulties in the process of commercialisation. For instance, patenting procedures are often

[18] A complication in the analysis of localised knowledge spillovers is that the location decision of firms is endogenous. This could mean that innovative firms consider the proximity of a university to be an important factor in the location decision.

complex and time-consuming.[19] Another constraint to start a spin-off company comes from the limited availability of financial resources. Scientists who want to start a company may meet difficulties to obtain credit from commercial banks. We will discuss capital market constraints in more detail in the next chapter.

An entrepreneurial attitude in academia can also be promoted by bringing science and industry closer together. Such closer proximity also helps to better exploit knowledge spillovers. As we have seen, knowledge in codified form (e.g. written down, expressed in a formula, or in a design) is easy and almost freely transferable by e-mail, fax, etc. Spillovers of codified knowledge are near to perfect. However, not all pieces of knowledge can be codified, and part of the knowledge stock will remain tacit (e.g. in people's heads). The transfer of tacit knowledge requires some form of personal contact. Therefore, tacit knowledge transfer is localised. Spillovers are localised when the impact of research in place x on output in place y is a function of the geographic distance between x and y. When spillovers depend on distance, it can be expected that innovative activity will cluster in regions where knowledge spillovers are the most prevalent (Audretsch and Feldman, 1996). This might shed light on the emergence of highly innovative regions such as Baden-Württemberg, Silicon Valley and Boston.

3.4 Determination of the academic research agenda

A large discrepancy between scientific and business research agendas may severely limit opportunities for science-industry interaction. Some differences in specialisation patterns of public and private research may be justifiable in terms of knowledge externalities and public tasks such as health, safety and environmental concern (Rensman, 2004).[20] But the allocation of funds for public research as a result of historically determined factors, which is common practice in many countries, may be suboptimal.

University research is typically financed from three main funding flows: basic research funding, competitive research funding, and contract research funding. The relative sizes of these three funding flows and the allocation principles differ substantially across countries (see Box on funding in the Netherlands). The determination of the research agenda within these

[19] Owen-Smith and Powell (p. 28, 2001) report the following citation of a faculty member: "For people like me awareness of patenting is essentially zero. I probably know less about that than I do about Medieval European social history. Really, that happens to be something that I am interested in. There is no information provided here, no advice urged upon us. If we wanted to do anything about this we would have to be very highly motivated to go out and seek the information, get the advice. We would have to, I think, be more sophisticated than most of us are – than I certainly am – to know when to do that or what sort of thing should trigger it."

[20] Jaffe (1989) and Mansfield (1995) both find that academic research in drugs generate the largest spillovers to firms compared to all other fields. Based on the Yale survey among 650 R&D directors in large US firms, Klevorick et al. (1995) provide a classification of fields of university research according to their relevance for firms. Computer sciences, material sciences and mechanical engineering rank at the top. On the other hand, geology, physics and mathematics score very low. However, in certain fields much of the spillovers may well be indirect. For instance, fundamental research in physics, probably of little use to firms, is beneficial to mechanical engineering, which itself is very relevant for firms.

disciplines follows scientific criteria dictated by international mainstream science, and there is generally little overlap between the various disciplines.[21] A potential solution to improve the match is to increase the share of industry funded research at universities. Firms typically finance research that they can use.[22] Another option is to reconsider the research funding structure. Owen-Smith et al. (2002) argue that the highly decentralised US university system, in which scientists must compete for funding, creates a larger mix of disciplines than the hierarchic European system.[23]

University research funding flows in the Netherlands

In the Netherlands, basic research funding is granted to universities largely based on historical allocations (Pomp et al., 2003). Universities can freely dispose of this budget. The second financing source of university research, competitive research funding, is mainly granted by the Netherlands Organisation for Scientific Research (NWO), based on the quality of research proposals. A small part of this budget is granted by the Technology Foundation STW, which finances technological projects on the basis of research quality and utilisation by firms.[a] The third source of financing corresponds to contract research activities for the government or the private sector. The distribution between these three financing sources is about 56%, 8% and 36% for the three types of flows (in 2003), respectively (see Pomp et al., 2003).[b]

[a] STW is a division of NWO. Also, NWO promotes science-industry interaction through the so-called 'Regieorganen' such as NROG (coordinating genomics research) and ACTS (coordinating research in the field of advanced catalytic technologies for sustainability).
[b] These numbers are averages, and the distribution might differ across disciplines.

3.5 A trade-off between science-industry interaction and fundamental research?

Do stronger links with business threaten fundamental research at universities? There are often-heard concerns that commercialisation in academia may have two unintended consequences:

1. More secrecy, leading to less disclosure: stronger links with business could reduce the disclosure of academic output, due to a conflict in the incentive structures of universities and the business world;
2. Shift away from fundamental research: stronger ties with business could crowd out fundamental research to the benefit of more applied research by academics.

[21] According to Klapwijk (2004), the unbalanced relationship between science and industry in the Netherlands is connected to the distinction between general and technical universities, reflecting the division of fundamental and applied research.
[22] The often-mentioned drawbacks from increased contract funding do not receive robust support in the literature. For instance, a survey among university professors in Norway suggests that industrial funding introduces new and interesting research topics, and industrial funding is positively correlated with publication output (cf. Gulbrandsen and Smeby, 2005).
[23] The financing of research is considerably more centralised within European countries. This entails more hierarchical control. For instance, in Germany a number of the prestigious Max Planck institutes are organised hierarchically around a single academic discipline. An exception is Finland, discussed in Chapter 5.

Below, we sum up the evidence in the empirical literature. The main conclusion is that the above mentioned concerns do not receive robust empirical support.

More secrecy at the cost of disclosure?

The conflict between the norm of disclosure of science and the secrecy norm in the business sector might increase if the link with the business sector becomes stronger (Dasgupta and David, 1994; Stephan, 1996). Academic scientists may be limited in their freedom to publish results from industry-funded research. The fact that not all research results are disclosed reduces the social benefits from university research. For instance, secrecy could lead to useless duplication of research, slowing down the advancement of science. Furthermore, it diminishes broader technological transfer towards other firms which are not collaborating with universities.[24] Cohen et al. (1998) suggest different policy options to solve the conflict between disclosure and secrecy. The government could tie tax benefits offered to firms who collaborate with universities to strict disclosure conditions. An alternative is that universities set up their own rigorous guidelines for research disclosure when working with firms.[25]

Several case studies bring up evidence that disclosure restrictions and delays in publications do occur in practice. In their widely cited survey of Industry/University Cooperative Research Centers (I/UCRCs), Cohen et al. (1994) find that 35% of the research centers allowed firms the ability to delete information from reports and 50% allowed firms to delay publications. Blumenthal et al. (1997) find similar evidence of disclosure restrictions among researchers in life sciences who received industry support. In their analysis, delaying publication longer than 6 months was predicted by two main variables: receiving funding from industry and being involved in commercial activities.

But the empirical literature also provides some counterevidence. More specifically, publishing and patenting by scientists seem to be complements rather than substitutes. Stephan et al. (2002) study the hypothesis that faculty patents crowd out faculty publications, i.e. that scientists engaged in patenting activities have incentives to restrict disclosures of findings and thus publish less. Using data on the Survey of Doctorate Recipients about publishing and patenting activities in different academic fields, they find that the number of articles published in the last five years has a strongly positive (and statistically significant) connection with the number of patents issued in all fields, except computer sciences. In other words, patenting and publishing are two complementary activities, rather than substitutes. This can be explained by the fact that scientists may want to publish some results, while monopolising the use of some other findings, so that it becomes more difficult (or even impossible) to reproduce their work. Similarly, in a related study at two departments at MIT, Agrawal and Henderson (2002)

[24] Dasgupta and David (1994) make the parallel with a classic prisoner's dilemma game, in which everyone ends up withholding results, while the collective interest is to share information.

[25] A drawback from these regulations can be that firms become more reluctant to outsource their research to the higher education sector. The advantages of the secured disclosure of research results should then be weighted against reduced financing from the market.

conclude that patenting is not substituting for more fundamental research, and might even be a complementary activity. Another study is Behrens and Gray (2001), who find no evidence for the claim that industry sponsorship would result in erosion of academic freedom (using data on graduate students at six US universities). Sponsorship by firms has no negative effect on outcomes in terms of publications, career goals, and perceived academic freedom. It should be noticed that these results may suffer from selection problems, e.g. when industry selects well-known scientists to work on projects and scientists are steered towards patenting.

Shift away from fundamental research?

The second main concern on stronger links between science and industry is that this would shift academic research away from fundamental research to more applied research. Fundamental research generally focuses on long-term risky research projects, which would not be produced by the market otherwise. This is precisely the reason to keep this type of research in the public domain. Basic research may not result in ready-to-use applications, but can lead to discoveries and scientific breakthroughs with potential for further development and commercialisation. Too much emphasis on applied research can come at the cost of fundamental research, which may damage the economy's innovation potential. Furthermore, the benefits from applied research are easier to internalise, so that the balance between public and private funding could change to the latter (less government funding is needed to correct for knowledge spillovers).

The evidence does not provide robust support that there is a shift away from fundamental research. In interviews conducted by Mansfield (1995), over half of the interviewed academic researchers acknowledge that the new problems and ideas they were working on stem from their interactions with the industrial world. Half of the interviewers also reported that the direction of their work was influenced by potential sponsors and users. In other words, collaboration with industries may affect the research agenda of universities. The study of Mansfield is, however, limited to a few disciplines, like electronics and chemistry, which are already very applied.[26] Thursby and Thursby (2000) find that increased university licensing is not explained by the fact that university-industry collaboration leads to a shift towards more applied research. Instead, the cause of the growth of university licensing is a switch in scientists' behaviour. Academic scientists became more inclined to license and patent their results, mainly due to a new entrepreneurial climate within universities. The finding by Blumenthal et al. (1997) that industry-funded research tend to be applied and short-term may simply be due to the fact that scientists who were already doing a lot of applied research attracted more industry funding. Mowery and Ziedonis (2002) confirm this intuition. They find that the faculties experiencing the largest patenting growth all had a long history of applied research.

[26] Or, perhaps better, were the difference between applied and basic research is less clear.

In conclusion, there is no strong evidence in the literature that science-industry interaction leads to problems in the disclosure of scientific research results or to a shift away from fundamental research to applied research in academics.

4 Potential barriers within the private sector

In this chapter we discuss factors from within industry that may be responsible for a suboptimal knowledge transfer. We identify three types of barriers. First, the firm's potential to benefit from knowledge spillovers, or its absorptive capacity, depends on the firm's own R&D efforts. Second, firms may find it difficult to obtain capital for their research projects because of capital market imperfections due to asymmetric information problems. The market has developed solutions that counterbalance these information problems, but concerns are expressed about decreasing availability of venture capital after the boom around the millennium. Finally, agency problems within the firm could entrench a lazy management, unwilling to innovate or adopt new technologies.

4.1 Introduction

In addition to universities, firms may also have suboptimal incentives to make use of the knowledge supplied by universities. A review of the literature provides three potential barriers within the business sector:

1. Limited absorption capacity;
2. Capital market imperfections;
3. Incentive problems within firms.

A firm needs absorptive capacity to be able to use scientific knowledge, and this absorption capacity is dependent on the firm's own research efforts and its connections with the scientific community. A lack of absorptive capacity may be the dominant barrier in firms to effectively interact with universities. The problem of credit market imperfections can partly be solved by the market, and is more like a precondition to carry out R&D (thereby increasing absorptive capacity). Internal information problems cannot be solved directly through government intervention, although indirect policies (such as competition policy) could reduce these problems. The following analysis shows how these barriers within the business sector hinder effective utilisation of scientific knowledge.

4.2 Limited absorption capacity

A firm needs absorptive capacity to be able to use scientific knowledge, and this absorption capacity is dependent on the firm's own research efforts and its connections with the scientific community. While research results are often accessible in codified form, such as in scientific journals, it may be very difficult for firms to absorb this scientific knowledge unless it has extensive expertise of the field. Therefore it is presumed, and supported by some empirical evidence, that a firm has to do some research itself in order to understand it.

Cohen and Levinthal (1989, p. 569) define absorptive capacity as “the ability to exploit outside knowledge of a more intermediate sort, such as basic research findings, that provide the basis for subsequent R&D”. They argue that absorptive capacity depends on the firm’s own investment in R&D. Hence, R&D has a dual role. R&D increases innovation, yielding new products and ideas. R&D also builds absorptive capacity, so that firms are better able to make use of knowledge from outside the firm.

R&D spending might be increased by firms so as to increase their absorptive capacity. Indeed, one of the main reasons that firms invest in R&D is to “keep abreast of the latest (…) developments and to facilitate assimilation of technology developed elsewhere” (Tilton, cited in Cohen and Levinthal, 1989, p. 569). This concerns knowledge developed by other firms such as competitors, suppliers and customers, but also basic or scientific knowledge from universities.

The need to build absorptive capacity depends on the distance between own and outside R&D. According to Cohen and Levinthal (1989, p. 572), “when outside knowledge is less targeted to the firm’s particular needs, a firm’s own R&D becomes more important in permitting it to recognize, assimilate and exploit valuable knowledge.” Cohen and Levinthal (1989) find in their empirical study that more outside applied science reduces own R&D, but more outside basic science increases own R&D, presumably because basic science is less targeted and therefore more difficult to absorb.

However, doing basic research is costly and uncertain. This makes R&D less profitable and may reduce private R&D spending.[27] Particularly small firms cope with this problem (see Box). To elaborate on this a bit further, one could interpret the idea of absorption capacity in terms of costs and benefits: exploiting knowledge developed in the public sector is costly, and one has to invest in R&D in order to be able to capture this public knowledge. Or, in other words, spillovers are endogenous, and depend on one’s own R&D efforts. When firms have high expectations of future returns from public knowledge, they will make the R&D investment. When expectations are not so glorious (relative to the associated costs), they might abstain from investing in absorptive capacity through R&D activities.

Other factors may also increase absorption costs for firms, such as a large difference between the public and private research agenda.[28] This implies that absorbing some particular scientific knowledge requires that the firm’s own R&D should also be partially directed towards scientific research in a similar field.

[27] For the design of R&D policy it is important to know whether absorption costs increase or decrease R&D investments. In the former case, the notion of absorptive capacity could partially counterbalance other factors leading to suboptimally low R&D investments. This may imply that R&D subsidies would be less important than currently thought. But if absorption costs reduce R&D investments further below the optimal level, policies that increase R&D investments become more valuable.

[28] Research in the public sector should in principle focus on basic science. However, if the industry is not sufficiently advanced to utilise the research (in terms of absorptive capacity), there is little public value. One strategy could then be to move the public research agenda towards the private sector in order to create absorptive capacity. However, as private firms become more sophisticated in their own research activities (think of the pharmaceutical industry), society may benefit most from fundamental research in the public sector. Hence, the optimal public research policy is linked to the absorptive capacity of the private sector.

Lim (2000) and Nooteboom et al. (2005) extend Cohen and Levinthal's concept of absorptive capacity. Lim (2000) argues that absorptive capacity also increases by connectedness to the open science community. In addition to in-house R&D, absorptive capacity is built by funding research at universities, hiring graduate students, engaging in research consortia, and so on. Nooteboom et al. (2005) consider the relation between cognitive distance and innovation performance of firms engaged in private research collaborations, which may also be of relevance for public-private research collaborations.[29] Two opposing forces are at work. The so-called novelty effect increases with cognitive distance, because more learning opportunities arise for novel combinations. The opposite effect is that absorptive capacity decreases with cognitive distance, as mutual understanding to utilise those opportunities is reduced.[30]

Absorptive capacity and firm size

Small firms might have a lower absorptive capacity than larger firms. The reason for this is that small firms have less in-house R&D to build capacity (Cohen, 1995), and have less connections to the scientific community (except for small high-tech start-ups). The Third Community Innovation Survey (CIS-3) provides data on firms with innovative activity within the EU countries, categorised by firm size.[a] These data show that smaller firms are less likely to have some form of innovative activity between 1998 and 2000. Small firms have less often in-house R&D, are less often involved in innovation cooperation, and less often mention universities as a highly important source of information for innovation.

Innovative activity by size of firm (%), 1998-2000

	Proportion of enterprises with innovative activity		Of which involved in innovation cooperation		Of which citing sources as highly important for innovation			
					In-house R&D		Universities & other higher education inst.	
	EU	NL	EU	NL	EU	NL	EU	NL
Total	44	45	19	24	38	51	5	2
Small	39	39	14	18	34	50	4	2
Medium	60	59	24	30	41	52	5	3
Large	77	79	57	48	70	57	10	3

Note: small = 10-49 employees; medium = 50-249 employees; large = 250 or more employees.
Source: CIS-3, Eurostat (2004).

[a] See also Chapter 2.

[29] Cognition refers to a broad range of mental activity, including proprioception, perception, sense making, categorisation, inference, value judgments, emotions, and feelings, which are all interrelated.

[30] Nooteboom et al. (2005) find for 994 inter-firm alliances in several US industries over the 1986-1996 period an inverted-U relationship, implying the presence of an optimal cognitive distance between research partners.

4.3 Capital market imperfections

A second barrier for firms might be a lack of capital to invest in R&D projects undertaken to commercialise scientific knowledge. This barrier is caused by asymmetric information problems on the capital market.

The benefits of R&D investments are inherently uncertain. Some new products will become blockbusters, others will never make it to the stores' shelves. Firms often have not enough own capital to wash out these risks. For that reason, risk averse managers tend to underinvest in R&D. However, the managers may try to attract external funds. The capital market can reduce much of the risk by holding diversified portfolios which makes R&D investment mutually interesting.

However, the shift of risk towards the capital market creates incentive problems, which can result in underinvestments after all. This creates a dilemma between diversifying risk on the one hand, versus incentive problems on the other hand. The underlying cause of the incentive problems is the asymmetric information among parties. The researcher or manager is usually better informed about the prospects of R&D projects than the bank which finances the project. That is, the researcher / manager knows better which research projects are most promising, and he is better informed about his own ability and efforts. If the researcher / manager does not bear the full risk, fewer incentives exist to select the high quality projects or to make efforts. By carrying some of the risk, the bank therefore faces incentive problems.

The asymmetric information problem manifests itself in two phenomena: moral hazard and adverse selection. Consider first the adverse selection problem. The basic idea is that the researcher knows better than, say, the bank manager whether he himself or his project is of high or low quality. The lower the quality, the less chance there is on success and therefore the greater the probability of insolvency. Since the bank cannot really tell whether it is dealing with a low or high quality project, all that the bank can do is to calculate a premium based on the average. Such a premium is unattractive for high quality projects. Consequently, only lower quality projects will apply for a loan. But these are uninteresting for banks. Therefore, banks will only finance projects that are evidently promising, but not the other projects. Thus, the capital market works in an inefficient way because some good projects will not be executed even if it would be socially optimal if they were.

In addition, the researcher may have an informational advantage with respect to his behaviour in terms of efforts or project choice. If the bank cannot perfectly monitor the researcher's behaviour, the researcher can be tempted to study what he finds interesting rather than what is best for the firm, or decide to take it easy and be lazy (moral hazard). This reduces the probability of success and leads to underinvestments in a way identical to adverse selection.

These information problems are especially relevant for knowledge that is still in an early development phase like basic science. Capital market imperfections are therefore likely to be severe for projects depending on basic science. This may lead to scientific ideas or proposals that remain idle because no capital can be attracted to finance these projects.

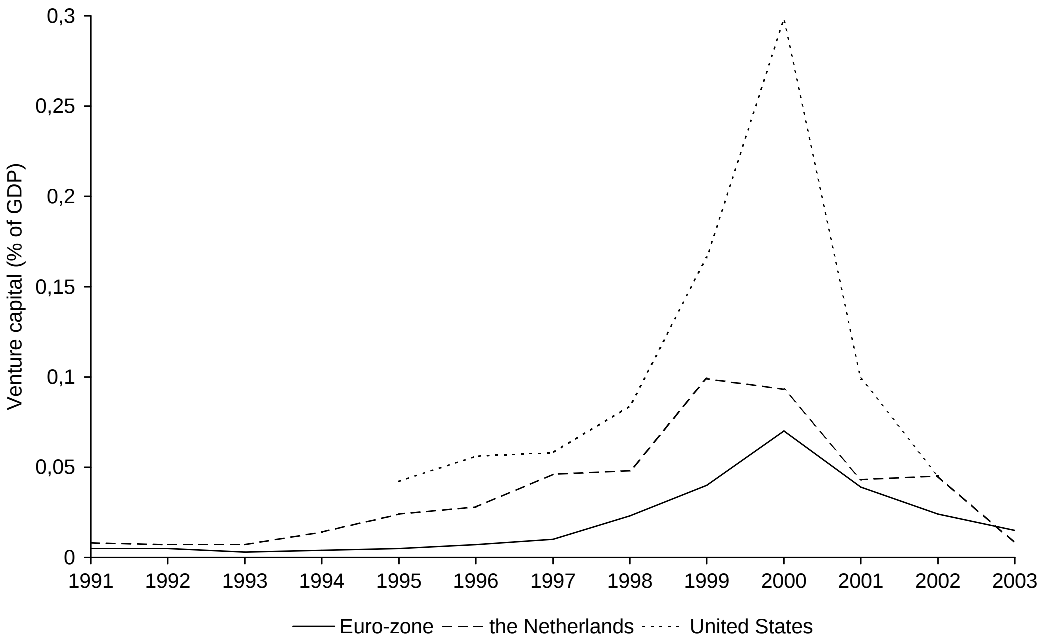
The market has nevertheless found some solutions that at least partly mitigate incentive problems due to the shift of risk:

- The threat of a takeover may discipline researchers and managers. For example, according to Jensen (1988), "when the internal processes for change in large corporations are too slow, costly, and clumsy to bring about the required restructuring or change in managers efficiently, the capital markets, through the market for corporate control, are doing so. The takeover market serves as an important source of protection for investors in these situations" (p. 28).
- Capital can be provided by more specialised investors who have expertise on the technology. This is often the case with venture capital. Because venture capital investors are better informed, they run less risk of financing bad projects and they can better monitor the manager's behaviour. Especially at the early stage of development, when there is a lot of uncertainty, venture capital can be an attractive option.
- Rather than providing loans with a fixed interest rate, capital can be provided in such a way that it induces more powerful incentives. Carefully designed compensation contracts can reduce incentive problems. For instance, instead of providing capital for the next ten years, it can be provided for a single year with a prolongation of finance contingent on intermediate performance. Investors could then refuse to provide more capital and even block the firm in its ability to raise capital from other sources, if performance is unsatisfactory (Lerner, 2000). Venture managers can also be given compensation packages with profit-sharing provisions. This way managers are rewarded for making successful investments (and harmed in case of failure). Finally, venture capitalists can be given direct control in the advisory board with the option to replace malfunctioning managers.
- Another option is to cooperate with other firms, like in research joint ventures (RJVs). This way, costs are shared among participants and the need for external funds is reduced. According to Baumol (2002, p. 94), cost-sharing is the most frequently given reason for sharing technological information. Of course, although it takes away incentive problems between external investors and firms, cooperation creates a whole new set of possible incentive problems such as free-riding behaviour among participants.

Despite the market solutions, it is often argued that there is still a lack of capital. A lack of venture capital is particularly worrisome, as this kind of capital is especially intended to start high-technology firms. Although venture capital as a fraction of GDP has steadily increased during the nineties, peaking around the millennium, the trend has reversed in recent years (Figures 4.1 and 4.2). In most countries the amount of venture capital has been decreasing, in particular for early stage investments (seed capital). A large part of the peak around 2000 is explained by the ICT-hype and favourable business cycle, but the subsequent decrease is rather sharp, with venture capital as a fraction of GDP returning to pre-1995 levels. However, in the Netherlands, the provision of venture capital is still perceived as relatively plenty compared to other countries, as the Global Competitiveness Report 2004-2005 shows (see Table 2.2).

It should be noted that a limited use of venture capital may not be only due to a supply restriction, but also to demand factors. Entrepreneurs apparently do not want to attract too much external funds, as this reduces discretionary control. Goodacre and Tonks (1995) report that for San Francisco venture capital seems relatively unimportant, even though the venture capital market is well developed in this region. Venture capital accounted for less than 15 percent of total financing of small high-tech firms in the mid-1980s.

Figure 4.1 Seed capital



Source: Eurostat.

Figure 4.2 **Expansion capital**

Source: Eurostat.

4.4 Incentive problems within firms

Information problems can equally well create incentive problems within firms. Especially in large firms, research is often organised in separate departments. This makes monitoring of research activities by general management more difficult. Therefore, researchers and managers of the research department have some discretion over their efforts.

An assumption commonly made in the corporate finance literature is that managers minimise private costs associated with innovation, such as training costs or costs of switching to new technologies (Aghion and Howitt, 1998). Thus, they may postpone the adoption of a new invention as long as possible. They may wait up to the point where the firm starts to make losses with the current technology. Evidently, postponing adoption of new technologies as long as possible is in conflict with profit maximisation and leads to suboptimal slow adoption of new technologies.

It is difficult for the government to design a suitable policy to combat these internal incentive problems. Policy will be more indirect, like competition policy. For instance, with fiercer competition, an existing technology becomes loss-making earlier in time because profits are reduced. Therefore, more intense competition forces a manager to adopt a new technology earlier (Aghion and Howitt, 1998).

5 Policy initiatives to promote science-industry transfer: Foreign experiences

What can we learn from foreign experiences with policies to stimulate science-industry interaction? In this chapter we discuss a number of interesting policy initiatives taken in the US, Finland and Israel. We link these initiatives to the various barriers identified in the previous chapters. For example, Technology Transfer Offices in the US aim to promote an entrepreneurial attitude among scientists, among other things by providing technical support in the patent application process and by establishing contacts with the business community. We try to evaluate the various initiatives in terms of their success with respect to science-industry interaction. One general lesson is that the specific design of the instrument determines its success. Successful instruments anticipate and take account of behavioural responses by its recipients. Another conclusion is that convincing evaluation studies are scarce, are studies based on experiments are a promising research strategy to identify the causal effect of the program.

5.1 Introduction

The current chapter discusses foreign policy initiatives to boost science-industry knowledge transfer (we postpone the discussion on Dutch policy to the next chapter). The international policy initiatives are classified by their focus to remove or reduce the various barriers to science-to-industry transfer identified in Chapters 3 and 4. We discuss instruments by barrier, abstracting from possible interdependencies.[31]

One general lesson is that the specific design of the instrument determines its success. Successful instruments anticipate and take account of behavioural responses by its recipients. For example, the Israeli Yozma venture capital program corrects for information problems connected to the provision of credit through a mechanism rewarding success and providing financial expertise.

In order to assess which instruments are the most effective and efficient, we need to get insight into the causal impact of the policy: to what extent can the observed effects of a certain intervention be attributed to that intervention? Such type of evaluations call for a proper control group, which can be obtained from natural or controlled experiments.[32] To date, this is becoming more and more the standard methodology in the economics literature. For most instruments reviewed in this chapter, evaluations with a control group are not available so that our understanding of the policy effects is very limited. A complication is that most instruments aim to reduce more than one market imperfection, and do not focus only on science-industry interaction. Moreover, several measures are used at the same time, so that the effects of the

[31] We will briefly discuss the notion of a so-called optimal policy mix in Chapter 6.

[32] In order to evaluate the effectiveness of a policy instrument, a control group has to be created or identified, which consists of persons or firms who have not used the instrument, but do not differ (or hardly differ) from persons or firms within the group that has used the instrument (Cornet and Webbink, 2004).

individual instruments are difficult to separate. In these cases, we can only provide a qualitative analysis of their potential effects on science-industry interaction.

5.2 Rewarding scientists: The Bayh-Dole Act (US)

The majority of studies on rewarding scientists address the question whether monetary incentives affect the scientists' propensity to patent. The US Bayh-Dole Act and its impact on the behaviour of scientists have received particular attention in the literature.

The Bayh-Dole Act in the US

The Bayh-Dole Act from 1980 allowed American universities to patent and license their inventions from federally funded research.[33] The Bayh-Dole Act had its origin in the 1970s, when there were concerns about the overall US technological performance. At that time, it was common practice for the government to take title of inventions from federally funded research, and to issue royalty-free non-exclusive licenses. Consequently, only 5% of federally-owned patents were licensed, and the non-exclusiveness of licenses seemed to preclude joint research investments by government and private companies. As federal funding accounts for about 60% of all research expenditure, rules for governing intellectual property rights (IPR) on federally-supported research could greatly affect university patenting and in turn technology disclosure.

In the US, university patenting and licensing activity grew rapidly from the early 1980s on, but a causal impact from the Bayh-Dole Act is difficult to establish. Private R&D also increased, causing an increase in the overall number of patent applications. Nevertheless, Thursby and Thursby (2000) found, based on interviews, that the growth in university patenting could be attributed to a higher propensity of researchers to patent their inventions, without a shift in their research activities to commercially more interesting fields. Universities typically share licensing revenues with the researcher, and they have discretionary freedom to choose their own internal reward structure. Lach and Schankerman (2003) find that universities offering a higher royalty share to academic scientists generate more inventions and higher license income (controlling for other factors such as university size, quality, and research funding). They show that the incentive from royalties increase scientists' effort level and induce sorting of scientists across universities.

Colyvas et al. (2002, p. 2) argue that "the role of patents and exclusive licenses in facilitating the transfer of university technologies remains poorly understood". They study how university inventions get into practice by presenting a number of cases from Colombia

[33] It seems somewhat peculiar to grant intellectual property rights on publicly funded research, as IPR and public funding are two different instruments to combat the same market imperfection, namely private underinvestment due to knowledge spillovers (cf. Verspagen, 2004). However, university inventions typically need further R&D before they can be commercialised. Firms are normally only prepared to carry out the additional R&D if they can appropriate the full returns on their investments. That would call for an exclusive licensing contract with the university, which requires that the university (or its researchers) hold the intellectual property rights.

University and Stanford University. A basic premise of Bayh-Dole is that university inventions are 'embryonic', needing further development (usually by industry) to be useful. However, in four of the eleven studied cases the inventions were useful to industry, for instance because the firm had already easy access to the knowledge. In these cases, the university patent did not contribute to bringing the invention into practice; it merely allowed the university to generate income from licensing the patent. Furthermore, the strong exclusivity of a university license may sometimes endanger further development of university technologies. It is difficult to identify firms which have the capability to successfully carry out the additional R&D to commercialise the technology. In some cases, firms that received exclusive licensing rights backed out after a while. On the other hand, in two cases, firms that initially did not receive the exclusive licensing rights offered to take up the complementary R&D.

Another effect of the Bayh-Dole Act, not directly related to the reward structure of scientists, concerns the quality of patents. Henderson et al. (1998) showed that although the propensity to patent increased, the quality of patents and their commercial success went down. However, a recent study by Mowery and Ziedonis (2002) refutes this conclusion. They showed that the supposed decline in the quality of university patents was due to learning effects from the entry of universities unfamiliar with patenting and licensing. Furthermore, Sampat et al. (2003) found that part of the apparent decline in quality was due to an intertemporal shift in the citation rate to university patents. Citation rates did not drop, but citations only occurred at a later stage in the technology life cycle.

5.3 Entrepreneurial academics: TTOs (US) and science parks

How can the entrepreneurial culture within academia be improved? According to Lazear (2004), entrepreneurs must be jacks-of-all-trades to some extent, while scientists are specialists. Acknowledging that scientists and entrepreneurs have different comparative advantages, we here discuss two policies to promote entrepreneurship in academia without the intention of transforming the professor into a business man.

Technology Transfer Offices in the US

Technology Transfer Offices (TTOs) fulfill functions such as introducing scientists to the business world, building up networks of industrial partners, setting up guidelines for the commercialisation of research findings, managing and licensing university owned patents, etc. These TTOs emerged at various US universities in close relation to the 1980 Bayh-Dole Act. However, although crucial, it was not only the 1980 Bayh-Dole Act that initiated their rise.[34]

[34] One of the ideas behind Bayh-Dole is that financial incentives are needed to induce universities to advertise their inventions and communicate their economic potential to industry.

The advent of biotechnology and, more generally, research in life sciences also boosted their number.[35]

Rogers et al. (2000) find that universities characterised by a larger number of staff for TTOs, higher faculty salaries and more federal and industrial resources, had a higher technology transfer effectiveness score.[36] This shows up in the highly skewed distribution of licensing revenues across patents and universities. High-income earners, such as Dartmouth, Columbia University and Florida State University, generate 30% or more of their research budgets from intellectual property rights. The vast majority of universities, including Stanford and MIT, earn less than 10% (OECD, 2003).

Lach and Schankerman (2003) show that TTOs at private universities proved to be more productive than their public counterparts in terms of generating licensing income. Private universities have a greater responsiveness to royalty incentives compared to public ones. TTOs at private universities were found to make more use of performance-based pay (i.e., a royalty-sharing schedule), to be less constrained in their freedom of operation by regulations, and to be more focused on general income rather than on 'social' objectives such as promoting local and regional development.

One way for firms to learn about university inventions is via membership in broader scientific networks, limiting the role of the TTOs. However, TTOs can be important for inventions that generate little industrial interest early on. In some of the eleven cases studied by Colyvas et al. (2002) there seemed to exist a wide gap between academia and industry, but in seven cases strategically located people in industry were well aware of the university research projects, even before the universities began to market their inventions.

Science parks

A science park is typically a public-private initiative to strengthen the formal and operational links of the business community with a university, higher education institute or research centre on a location. It is designed to encourage the formation and growth of innovative businesses and other organisations in the park.[37]

As mentioned in Chapter 3 and 4, the transmission of knowledge can be bounded by distance when knowledge is tacit. Transfer of tacit knowledge between people requires some form of social interaction, and knowledge spillovers have a local character. To better exploit such localised spillovers, one could bring firms in close proximity to universities.

[35] Today, at least 70% of all licensing income earned by universities is generated by life science patents.

[36] This score incorporates the number of invention disclosures, the number of patents, the number of licenses / options executed, the number of licenses yielding income, and gross income received.

[37] An extensive literature exists on policy initiatives with imaginative names like techno-cities, science cities, technopoles, and science parks. What all these instruments have in common is that they aim at regional development and intend to stimulate knowledge transfer between private companies and research institutions located in a particular region.
We do not want to get stuck in definition issues, and confine ourselves to the concept of science parks.

Do science parks stimulate entrepreneurship among scientists? The effects of science parks are rather complex, involving spin-offs from universities and settlement of firms in the park in order to increase their opportunity or capacity to absorb scientific knowledge via direct interaction. Case studies on Linköping Technopole (Heydebreck et al., 2000), Madison University Research Park (Ylinenpää, 2001), and Silicon Valley (Hall and Markusen, 1985), show that many spin-offs were developed in these regions. Löfsten and Lindelöf (2002) state that firms located in science parks are significantly more likely to have a link with a local university than off-park firms.[38]

What makes a science park successful? Saxenian (1985) mentions two characteristics, namely the presence of a university with advanced and preferably technical and applied research, and a relationship with a (normally) large, innovative and dynamic 'locomotive company'. Ylinenpää (2001) states that the above factors are not the only keys to success. He identifies two separate and distinct development strategies for a successful science park. First, the incubator strategy focuses on creating favourable conditions for commercialisation of research-based ideas in the form of spin-off companies from universities. Second, the attraction strategy is to encourage established and larger companies to locate knowledge-intensive divisions in a park close to the expertise and the recruitment base offered by a local university. However, following Porter's (1980) reasoning, science parks should be built on one of these strategies and not on a combination of the two, since each strategy requires a different set of measures. Furthermore, the effectiveness of a development strategy depends on the characteristics of the region. The case study of Madison University Research Park (in the US) showed that the initially followed attraction strategy failed because of severe competition from other parks, while this park flourished after adopting the incubator strategy (Hyer, 1999).

Should the government play any role in the provision of science parks? Appold (2004) concludes for Sweden that any policy intervention in the implementation of science parks is superfluous. In other words, the ability to shape the geography of innovation through local policy efforts appears to be limited.

5.4 Public research agenda: I/UCRCs (US) and Tekes (Finland)

Here we discuss an example of competitive support for research alliances between universities and firms in the US, and the research funding model adopted in Finland.

Industry/University Cooperative Research Centers in the US[39]

Industry/University Cooperative Research Centers (I/UCRCs) are small academic centers designed to foster research with strategic importance to industry, especially engineering. At the federal level, the NSF has stimulated such centers since the late 1970s. Within the NSF-

[38] This may not imply causality, due to as self-selection of knowledge-intensive firms on science parks.

[39] This part is based on CPB and CHEPS (2001).

program, universities and industry have to make joint proposals for a I/UCRC. When accepted, the new center receives a five year grant from NSF of US $70,000 annually. After this initial period, funding may be extended at a reduced level of $35,000 annually for an additional five years. Thereafter, the center is expected to be self-financing. I/UCRCs have to collect at least $300,000 annually of industrial support through membership fees, with a minimum of six industrial members. This last requirement should encourage a more generic research program.

From the I/UCRC-program some other cooperative NSF-programs evolved. Among these are the Engineering Research Centers (ERC) program initiated in 1985, and the Science and Technology Centers (STC) program established in 1987. The STC-program offers open competition among research fields, whereas competition within the ERC-program is restricted to engineering. So the STC-program has a somewhat stronger focus on multi-disciplinary research.

Do the I/UCRCs improve the match between the public and private research agendas? Unfortunately, the evidence is scarce. Cohen et al. (1994) find that most I/UCRCs tended to focus on relatively short-term research problems and issues faced by industry, at the cost of productivity in terms of academic papers. Together with the increase in the number of centers this might indicate a shift in the overall research agenda. On the other hand, Fitzsimmons et al. (1996) find that STC-papers tend to be published in journals oriented more toward basic than applied research. They also did not find evidence that STC-research is concentrated on the applied end of the spectrum compared to the average papers in the centers' respective fields.

Adams et al. (2000) do not find clear evidence in an econometric analysis to what extent I/UCRCs actually cause an increase in university-to-industry technology transfer. The observed effects may result from the fact that private labs which perform more R&D and produce more patents are more likely to participate in I/UCRCs. I/UCRC laboratories appear to be 2.5 times larger than private laboratories who do not participate in a I/UCRC. They further observe that I/UCRC membership is positively related with private laboratory patenting, and with private R&D expenditures. The analysis in Adams et al. (2000) does not allow firm conclusions, however. The effects are rather small, and not always statistically significant.

Mansfield (1995) found in his survey that half of the interviewed scientists reported that the dominant research problem on which they were working in the academic world stemmed from problems encountered during contacts with the industrial world. Cooperation with industry apparently often provides a stimulating environment that can generate new ideas for future research.

In addition to issues concerning the match between public and private research agendas, competitive support for science-industry interaction may also have other effects, such as improvement of research results, restrictions on the disclosure of these results, and career perspectives of academics.

For instance, NSF (1997) observes in a survey among 355 firm employees closely involved in ERC-centers that these employees were positive about the effects of center membership, although reactions differed between centers. Outcomes improve with the length of the membership and with the active involvement of industry researchers, articulating the importance of tacit knowledge. Fitzsimmons et al. (1996) show with bibliometric data that the STC-program yields highly cited publications. STC-articles were cited 1.7 times as often as the average US academic paper for the same journals in the same years. STC-papers achieved especially high relative citation rates in physics, biomedical research, and engineering and technology. Analysis of the centers' 1989-1995 papers revealed that the centers are publishing in journals with a somewhat higher impact than the average journal. Moreover, cooperating with firms may lead to more publishable results (which is obviously good for the academic status of the scientist).[40]

Restrictions on the disclosure of research results do exist. Blumenthal et al. (1997) carried out a large-scale survey in 1994-1995 among life-science academic researchers. They find that withholding of research results and publication delays were significantly associated with participation in university-industry research relationships and engagement in the commercialisation of research. However, the responses also indicate that practices of secrecy were not (yet) widespread, although underreporting may have taken place.

Regarding career perspectives, the question emerges whether collaboration with industry is good or bad for a scientist's reputation. Although this was typically not the case in the past, there is increasing evidence that scientists working with firms are gaining the esteem of their peers. Owen-Smith and Powell (2001), using results from a series of interviews among scientists, report that academics were more likely to patent when they had a supportive peer environment to do so, and when commercial success was valued in terms of academic status.

The Finnish model: Tekes

Finland is often mentioned as an example of effective innovation and technology transfer policies. The Finnish innovation policy aims at a greater relevance and efficiency of research. It emphasises the demand-side factors in the allocation of public research (Pavitt, 2000; Schienstock and Hämäläinen, 2001). Key policy issues are competitive funding, inter-institutional research cooperation and user involvement, including partial funding by these users. Universities are encouraged to enhance the exploitation of research results. Research proposals are evaluated on both scientific and practical benefits. The Finnish system is organised around several players, such as the Academy of Finland, the Science and Technology Policy Council, Sitra (a public venture capitalist), and Tekes, the National Technology Agency.[41]

[40] Stephan et al. (2002) and Behrens and Gray (2001) present evidence for this.

[41] For descriptions of the Finnish innovation system, see Wagner and Vocke (2001), and Werner (2003).

Tekes provides funds to universities and other public research institutions, to long-term research projects in companies, and to business projects aimed at the development of new products. All funds are distributed based on a competition between research proposals. Tekes' R&D budget amounted to 432 million euros in 2004, which covers 28% of the total public budget for R&D.

Approximately half of Tekes' budget is directed to the so-called Technology Programs. These programs each address a specific field or topic directly set by the board of Tekes. In this way, Tekes intends to influence research directions. Currently, Tekes has 23 ongoing technology programs. Tekes can freely distribute its R&D budget between universities and private companies. In 2003, 58.5% of its budget went to private companies, and 41.5% to universities and public research institutions. Besides requirements with respect to scientific topics, projects are evaluated based on two other important criteria, namely co-financing and cooperation. Tekes requires beneficiary firms to provide 50% project co-financing on average, and requires all large companies whose projects are co-financed to cooperate either with small companies, research institutions or universities. These research partnerships are considered very important in all evaluations of project proposals. Each project should at least contain two different partners, and additional partnerships are rewarded. The requirements are aimed to reduce possible market failures by spreading the financial risk of R&D projects. Furthermore, the cooperation between science and industry should maximise technology spillovers.

Robust evidence on the impact of Tekes on the public research agenda does not exist. It seems that the steering policy has worked quite well for Finland, although several studies indicate that specific (compared to generic) policy instruments like Tekes can backfire (Kealey, 1996; Schnaars, 1989). Perhaps the Finnish experience with specific support for firms like NOKIA is so successful because of the global ICT boom of the late 1990s. It is generally not the case that the government has superior information to pick successful industrial sectors, and the effectiveness of specific policies may be blurred by lobbying efforts.

Other evaluations, mostly internal reviews by Tekes, indicate positive effects on economic results. An example is Asplund (2000), who finds that the average productivity level and growth rate of firms receiving funding from Tekes is significantly higher than that of firms relying solely upon private R&D funding. However, some caution is in order. Results may suffer from selection bias (treatment is certainly not random).

5.5 Absorptive capacity: Fostering private R&D

Policies designed to facilitate absorption of scientific knowledge by firms include programs to foster private R&D activity, and the establishment of intermediary institutions. Here we discuss R&D subsidies and their side-effects on absorptive capacity.

Programs to foster private R&D activities

Policy instruments to increase private R&D investment (tax deduction programs, subsidies, or procurement) may have the side effect that absorptive capacity also increases. Unfortunately, to our knowledge, previous studies on the effects of programs to stimulate private R&D activities do not pay attention to the consequences for absorptive capacity. The available studies focus on the extent to which the subsidy leads to additional R&D spending by firms (compared to a situation without the intervention). The evidence on this so-called additionality is rather limited and mixed (see, for instance, Hall and Van Reenen, 2000). We cannot establish a connection between R&D programs and absorptive capacity on the basis of this evidence.

However, some criteria for a subsidy (or other measures) on private R&D investment might be of relevance for absorptive capacity. First, does the instrument stimulate firms to conduct more basic R&D to increase the firm's ability to exploit knowledge developed at universities? It may matter whether a condition for subsidisation is that the R&D project should be oriented towards the development of products and processes that are new to the *market*, or new to the *firm*. If it is only new to the firm, additional R&D activity due to the subsidy may be deployed for absorption of knowledge from other firms, suppliers, customers or other private parties. In contrast, knowledge that is new to the market usually concerns more 'basic' knowledge, that needs further development for commercial exploitation. If the subsidy is only granted for knowledge that is new to the market, the firm may devote relatively more of the additional R&D activity towards basic R&D. This idea deserves further investigation in future research.

Furthermore, it matters who gets the subsidy. Small firms are presumed to have a limited absorptive capacity (Cohen, 1995), and the speed of adoption is faster for larger firms (Karshenas and Stoneman, 1995). Two points may be relevant. First, especially small firms may suffer from capital market problems and risk aversion in the financing of their research activities. They have less collateral and limited possibilities to spread risks within a research portfolio. This may lead to relatively low R&D investments by the small firms. It can therefore be effective if public policies to stimulate private R&D investment give preferential treatment to small firms. These small firms may be more responsive to such R&D programs, and the indirect benefits in terms of increased absorptive capacity can be relatively large. On the other hand, economies of scale in R&D could render such targeted policies ineffective, and such economies of scale may be especially relevant for basic research. A second point is that a distinction should be made between high-tech starters and 'other' small firms. High-tech starters conduct more basic R&D, particularly the spin-offs from knowledge institutions. Their absorptive capacity in basic R&D is generally rather large, especially when compared to other small firms.

An alternative policy is to support firms in absorbing scientific knowledge. This can be achieved by allowing direct interaction between university and industry (such as in the I/UCRC-program), or by setting up intermediate knowledge institutions (like the German

Fraunhofer Institute or the Dutch TNO, see Chapter 6). Researchers at universities or knowledge institutions can take care of understanding basic research and translate it into commercial applications. Little is known about the effectiveness of these intermediate knowledge institutions, and currently we cannot assess which one of the two solutions is preferable.

5.6 Capital provision: Yozma (Israel) and SBIR (US)

Credit market imperfections can be corrected through direct public provision of capital. However, like banks and other capital providers, the government faces information asymmetries towards the researcher or project manager, rendering policy more difficult.[42] To alleviate these information problems, the government could require technical or managerial expertise. Another solution is to develop a more advanced financial system, offering better screening of projects (King and Levine, 1993) or disciplining researchers and managers (Aghion et al., 1999). For example, if the financial authorities allow banks to require larger collaterals, firms share more in the risk that banks take. Firms then will have incentives to work hard and select the most promising projects, so that the earlier mentioned moral hazard and adverse selection problems are reduced. An appropriate competition policy would be another alternative (Aghion and Howitt, 1998). Here we describe two specific policy instruments on capital provision: Yozma, a venture capital program in Israel, and the Small Business Innovation Development Act in the US.

Yozma, a venture capital program in Israel

Limited access to venture capital (VC) can hamper the creation of new high-tech firms, and thereby interfere with knowledge transmission from science to industry. The question then emerges whether there is a role for government in the venture capital market. Most European countries implemented public policies aimed at stimulating venture capital in the early eighties of the previous century. The scant success of such programs triggered disappointment with VC policies (cf. Florida and Smith, 1994). An exception is the Yozma program implemented in 1993 in Israel. An elaborate description of this program can be found in Avnimelech and Teubal (2002). Some important characteristics and distinctive features of this program should be mentioned. There were ten VC funds connected to the Yozma program, all focusing on early phase investments in Israeli high-tech start-up companies, and the management of each of these

[42] One might claim that provision of public support enables a researcher to start a project for which he could not attract other resources. However, it ignores the fact that a commercial bank may have had good reasons not to finance the project: it could not determine with enough confidence that the project is promising. Provision of capital can only be welfare improving if the government can make a better judgment, but this is questionable. The government may therefore end up financing projects of dubious quality. The same would be true for setting up government labs where research can be undertaken that the private sector would not perform otherwise. Of course, such policies can be good for other reasons, for instance when the (expected) social rate of return exceeds the private return. But the point made here is that they are unlikely to solve incentive problems related to information constraints.

funds involves at least one reputable foreign financial institution next to a local management company. Second, the government contributed in each of the ten funds under this program about 40% of the totally raised capital (about 8 million US dollars per fund). This public funding provided strong incentives to the ‘upside’, i.e. when VC investments were very profitable. Each Yozma fund had a call option on government shares at cost price plus a small interest within a 5 year period. No ‘downside’ guarantees were given. Finally, the Yozma VC funds were privatised in 1997.

Avnimelech and Teubal distinguish two extreme situations to describe the VC industry. First, the industry can be characterised by both private and social profitability. Second, it is also conceivable that companies in the industry have a strong social impact but are not privately profitable. In the latter case the presence of externalities and the divergence between private and social returns is a reason for government intervention. According to Avnimelech and Teubal, Israel’s VC industry in 1993 was best described by the former situation. In that case, industries might have evolved naturally, and it is not obvious that the government should intervene. However, an important feature of the Yozma program is that it is not merely the provision of capital, but that this program also attracted high quality professionals and ‘intelligent’ capital from abroad. While the Israeli experience with VC policy may not be exportable to other countries, it has shown that a careful design of the program will contribute to its success.

Another evaluation of Israeli VC funds is presented in Ber and Yafeh (2004). Their conclusion is that the VC industry may have increased the survival rates of young technology-intensive firms. They do not find evidence that VC funds are helpful in identifying high performers.

The US Small Business Innovation Development Act: SBIR and STTR

An alternative capital provision policy is pre-competitive financing (i.e. grants) to take R&D from the proof of concept stage to prototype. Thereafter, private financing should take over. An example is the 1982 Small Business Innovation Development Act in the US, to stimulate the economic development of cutting-edge research. This Act installed two programs: Small Business Innovation Research (SBIR) for public funding of research by small firms, and Small Business Technology Transfer (STTR) for public funding of research collaborations between private companies and public research organisations.

An SBIR project is organised in several stages. At the end of each stage, the project is evaluated and reviewed before entering a new stage. In this first stage, supported by a grant of US $100,000 for a period of 6 months, the feasibility of the innovative concept is explored. If the outcome of the evaluation is positive, researchers can apply for admittance to the second stage. Acceptance implies a two year grant of US $750,000. In the second stage, the actual research is conducted, resulting in a prototype product. The third and final stage involves product development and commercialisation. At that time, the parties can no longer rely on SBIR support.

The programs prescribe which partner should provide how much effort in which phase. For an SBIR project at most 33.3% of the costs in the first stage might originate from another partner than the small business. In the second stage, this percentage might at most be 50%. In case of an STTR project, partnerships are mandatory. The relative contributions from the small business should equal 40% to 70%, and from the public research organisation 30% to 60%.

Is the SBIR an effective instrument to provide capital for innovation to small firms ?[43] Lerner (1999) studies the private benefits of the program measured through sales and employment growth. To that end, a control group is constructed by selecting firms that closely resembled the beneficiaries in the second stage. Lerner finds that SBIR recipients enjoyed substantially greater employment and sales growth. Also, they were significantly more likely to receive VC financing. Unfortunately, no attempt is made to assess the social benefits of the program (including the possibility of business stealing[44]), and the results in Lerner are not undisputed.

[43] To our knowledge, no evaluations of the STTR are available.

[44] Business stealing implies that firms with a new innovation destroy the market of incumbent firms (Aghion and Howitt, 1998).

6 Policy initiatives to promote science-industry transfer: The Netherlands

In this chapter we review some important instruments to promote science-industry interaction in the Netherlands. We again link the instruments to the various barriers discussed earlier. For example, we discuss the Technology Foundation STW as a program to improve the match between public and private research agendas. One general conclusion is that little is known about the effectiveness of the instruments used to encourage science-industry knowledge transfer. Also, because the set of instruments shows some overlap and some initiatives may be redundant, the effectiveness of the total policy mix is of interest to policymakers. This calls for insight into interactions between the individual programs. Further research based on experiments can help to fill these knowledge gaps.

6.1 Introduction

In this chapter we discuss some major or otherwise noteworthy initiatives to encourage science-industry interaction in the Netherlands. Along the lines of the previous chapter, we try and link the instruments to the various barriers identified earlier. For each instrument we aim to get insight into its effectiveness, but our earlier comment that convincing evaluation studies are scarce (see the introduction in Chapter 5) also holds for the Dutch context. Furthermore, another relevant question concerns the effectiveness of the policy mix. Is the set of instruments reinforcing or conflicting with each other? This is an even more challenging question to which to date no clear answer can be given. Instead we discuss some general considerations about the concept of the policy mix.

6.2 Rewarding scientists: Patenting by public researchers and STW

In this section we discuss Dutch initiatives to promote patenting by scientists in the public research sector. It should be mentioned that adjustments in the reward structure might also be created by other instruments. For instance, the Dutch Innovation Platform and the Confederation of Netherlands Industry and Employers VNO/NCW recently proposed a reform in the system of basic funding for universities towards explicit reward of efforts to interact with business (Wijffels and Grosfeld, 2004; VNO/NCW, 2003).

Patenting in the public research sector

The Dutch government considers patenting primarily as the own responsibility of the universities (EZ, 2001).[45] In the US, on the other hand, publicly funded research institutions are

[45] Universities adopt their own reward policies. An example of a university with an active patent reward system for scientists is Delft University of Technology. At this university, 10% of the net revenues (revenues on a patent minus the costs of acquiring the patent) are given to the researcher or group of researchers who obtained the patent), until a maximum of 25000 euro. Net revenues in excess of 25000 euro are transferred to the faculty employing the researchers.

obliged to investigate the possibilities to commercialise their research. Before the Bayh-Dole Act, US government did not have an explicit technology transfer policy. Because intellectual property rights resulting from publicly funded research were directly appointed to federal state, too little disclosure resulted. In the Netherlands, on the other hand, universities have always been free to patent results from publicly funded research. Consequently, a low patenting activity at Dutch universities cannot be explained by an improper assignment of property rights (Verspagen, 2004). However, from the US experience we learn that revenue-sharing might significantly affect the researcher's propensity to patent (cf. Lach and Schankerman, 2003).

University patenting in the Netherlands

The number of patent applications by universities and other (semi-)public research institutions in the Netherlands has grown over the years (BIE, 2001). Although this might indicate an increase in public and private research interaction, the share of patents applied for by public research institutions is still relatively low compared to the total amount of national patent applications (less than 7%). However, Antenbrink et al. (2005) report that, measured by patent applications per 1000 researchers in this sector, the Dutch public research institutions perform on average (compared to other OECD countries). Verspagen (2004) challenges Porter's (2001) conclusion that Dutch universities have little contact with Dutch companies and that they file few patents. Verspagen states that Dutch universities rarely register patents themselves, but leave the patent decision, for instance, to a cooperating private partner.

In 2001, on initiative of the Netherlands Industrial Property Office (BIE), the Platform of University Patent Policy was installed to facilitate the development of patent policy based on national and foreign experiences. But national policy on intellectual property rights is affected by two international issues. The first is the implementation of a community patent within the EU. Patent costs in the EU are currently much higher than in the US, because the patent must be defended in each country separately. This argument, next to other reasons, might explain why European universities have a lower propensity to patent. In 2004, the European Commission reached an agreement on the community patent. However, the national governments are still arguing about its implementation. The second international issue is the discussion on grace periods (e.g. within the World Intellectual Property Organization). During a grace period (mostly no longer than one year), the inventor has the opportunity to apply for a patent after making his research results publicly known. This mechanism is already in force in countries such as the US, Japan and Canada. In the Netherlands, such a grace period is still debated. Proponents favour the publication or dissemination of their results without delay. Opponents argue that a grace period would create legal uncertainty. When potentially patentable results are published, any decision on their industrial use is blocked for several months.

Patenting policy of the Technology Foundation STW

The mission of the Technology Foundation STW is to promote the utilisation of the results from scientific research. STW is the science and technology division of NWO, the organisation managing competitive research funding (i.e. the second funding flow of Dutch universities; see also Sections 3.4 and 6.4). STW and the university or research organisation conducting a research project financed by STW have joint ownership of the research results. STW commits to patent the (commercially interesting) inventions, covering all costs made. STW subtracts these costs from any received licence revenues. The remaining revenues are transferred to the related research group,[46] which is obliged to spend these net revenues on research or education.

STW uses several licensing principles. The first principle is exclusivity. The research institution, however, maintains the right to publish and the right to use the results for scientific research and education. The second principle is secrecy. STW can demand the postponement of (scientific) publication for at most a year, if considered necessary for commercial purposes. The third principle is the use of royalty based fees, although sometimes companies pay a lump-sum. The final principle is an obligation to commercialise. When a license does not bring in a minimal amount of royalties, the exclusive right will be converted in a non-exclusive right or even be terminated.

In practice, STW relaxes these principles and separately negotiates agreements with interested users. STW actually receives more income on a lump-sum basis than from royalties (Table 6.1). Sometimes STW assigns (part of) the licensing income directly to the inventor, and not to his related department. This might positively influence researchers' propensity to patent.

Finally, users could acquire an option on an exclusive property right by contributions in kind, such as materials, laboratory space and personnel. The increase of the in kind contributions seems to result mainly from an increase in direct participation of user personnel in project-research ('collaboration in research' in Table 6.2). Collaboration in research might positively influence public-private research interaction. In addition, more users paid a fee to obtain a right on exclusive membership in a users committee ('confidential' in Table 6.2). The opportunity of exclusive commercialisation works as a positive incentive for collaboration. But secrecy also implies that broader knowledge transfer is ruled out, which may be undesirable from a social perspective.

Table 6.1 STW income received from users (in million euros)

	2000	2002	2003
Royalties	0.2	0.2	0.3
Lump-sum payments	0.3	0.5	0.6
Contributions	1.6	2.1	1.9
Contributions in kind	3.6	3.0	4.6
Total	5.7	5.8	7.4

Note: Contributions in kind are valued in monetary terms.
Source: STW (2000, 2002, 2003).

[46] More precisely, remaining revenues less than 50,000 euros are directly transferred to the research group; above 50,000 euros the amount is transferred to the institution and the research group on a 50/50-basis.

Table 6.2 Number of agreements with users

	2002	2003
Licence	13	7
Option	7	9
Option and licence	1	0
Collaboration in research	6	14
Patent transfer	6	6
Knowledge transfer	1	7
Confidential	11	17
Letter of intent	4	3
Other	4	6
Total agreements	54	69

Source: STW (2002, 2003).

6.3 Entrepreneurial academics: TechnoPartner and the Valorisation Grant

The US seems more successful than other countries in the creation of new spin-off companies. As stated by the OECD (2002), a Dutch public research organisation founds on average one spin-off per year. In the US, on the other hand, this average is two spin-offs per public research organisation (including universities).[47] Furthermore, US spin-offs are often led by an entrepreneur instead of a researcher which might contribute to their commercial success. In Section 5.3, we discussed Technology Transfer Offices (TTOs) in the US. In this section, we focus on policy instruments in the Netherlands, namely TechnoPartner and the Valorisation Grant.

TechnoPartner

The TechnoPartner program, introduced in 2004, targets at technostarters from both the public and private sector. The program emphasises the importance of science-industry interaction, and thereby focuses on spin-offs from universities and other public research institutions. TechnoPartner consists of four main components, namely the Subsidy program Knowledge Exploitation (SKE), TechnoPartner Seed, TechnoPartner Label and the TechnoPartner Platform.

The SKE (with a budget of 10 million euro per year) aims at public-private consortia that are willing to guide technostarters in the embryonic phase. SKE-subsidies can be used for scouting and screening of candidate researchers and technology, and for activities to improve patent policy. SKE can also provide subsidy to cover the costs associated with patent applications by public research organisations.[48] Furthermore, the SKE also contains a pre-seed facility, providing soft loans to explore the commercial feasibility of the company. The SKE requires a commitment of 50% of the full amount requested by the applicant. The

[47] Admittedly, we do not know to what extent this difference might be due to differences in scale (i.e. the average size of US universities compared to universities in the Netherlands).
[48] The size of the SKE subsidy depends (among other things) on whether the patent holder can license the patent.

TechnoPartner Seed Facility (24 million per year) aims to encourage the establishment of so-called Small Business Investment Companies (SBICs) by private parties (such as venture capitalists, large firms, and regional development companies). An SBIC is a private enterprise engaged in the financing of technostarters. When certain conditions are fulfilled, the private capital of the SBIC is matched by government loans. TechnoPartner Label provides a certificate which can be helpful in attracting credits. This policy instrument will be discussed in section 6.6. The TechnoPartner Platform (1.8 million per year) plays a facilitating role in the aforementioned initiatives, e.g. by providing information to (potential) starters. From 2007, the overall budget for TechnoPartner might be increased to 37 million euro per year (EZ, 2004a).

It is difficult to comment on the impact of this policy instrument. BioPartner, one of the predecessors of TechnoPartner, introduced a null measurement to comment on the point of departure (before policy comes in). Still, it is unclear whether or not these starters would have emerged without the subsidy. Furthermore, funded technostarters are involved in the construction of these null measurements, which could yield biased judgements.

According to Chamber of Commerce figures, 75% of the technostarters start without subsidy. Furthermore, only 2% of the technostarters come from universities and 4% from research institutions. Many successful technostarters seem to rely on the application of existing knowledge, rather than on new scientific knowledge. Finally, even if a technostarter originates from a public research institution, there is no guarantee that the connection is continued.

The Valorisation Grant

In 2004, NWO, STW, and TNO started a pilot on a new policy instrument, the Valorisation Grant. Based on the Small Business Innovation Research program (SBIR) in the US, this subsidy was installed to help starters or small companies to bring scientific research to the market. The focus is primarily on the commercialisation of knowledge from university research, and the main applicant for a grant has to be a university researcher, though the other applicants may come from small firms in the private sector. The Valorisation Grant consists of two phases. In the first phase, a researcher applies for a subsidy to explore the technological and commercial feasibility of the project. After this feasibility study, a researcher can apply for a second phase grant to develop a commercialisation strategy. This second phase requires the commitment of a private investor.

The effects of the Valorisation Grant cannot be recorded yet because it is still in a pilot phase, but some remarks can be made. First, the Valorisation Grant requires that the inventor should be employed by the starter for at least 50% of its time, while maintaining a connection to the public research organisation.[49] In this way, the program tries to consolidate the connection between the originating public research organisation and the firm.

[49] This is no requirement in the SBIR-program.

A second remark is that the pilot offers the possibility of a natural experiment and evaluation. In December 2004, the first 21 grants for feasibility studies have been awarded in a competition of 82 proposals. The referee committee (consisting of three entrepreneurs, three venture capitalists and three researchers with business experience) stated that 30 to 35 proposals were appropriate to receive the Valorisation Grant. But the budget only allowed acceptance of 21 of these proposals. The commercial quality of the other 9 to 14 proposals was considered high, as one of the committee venture capitalists decided to privately invest in one of them. These 9 to 14 rejected proposals form a control group, which can be compared to the experimental group of the 21 granted proposals. Comparison of the progress of rewarded and rejected high-quality proposals yields insight into the effectiveness of the Valorisation Grant.[50]

6.4 Public research agenda: STW, Bsik, IS, and TTIs

A number of Dutch policy measures which aim to improve the match between the public and private research agendas are:[51]

- STW, the Technology Foundation and its Open Technology Program;
- Bsik, the Decision for Subsidies for Investments in the Knowledge Infrastructure;
- IS, the Innovation Subsidy for collaboration projects;
- TTIs, the Top Technological Institutes.

Technology Foundation STW and the Open Technology Program

The Technology Foundation STW aims to finance and stimulate high-quality scientific research and to promote the utilisation of the results of this research. Among the various programs implemented by STW to fulfil these goals, the Open Technology Program (OTP) is the most important. In 2003, this program accounted for 78% of STW's budget of approximately 43 million euro for research projects.[52]

Research institutions from all disciplines are allowed to submit proposals to the OTP. Research proposals are judged by two criteria, i.e., scientific quality and utilisation aspects. Both criteria weigh equally in the final evaluation. The research proposals are evaluated in two stages. In the first stage five referees give (independent of each other) their view on the research proposal (peer review). Their reports, together with the response of the applicant, are evaluated by a jury in the second stage. This jury consists of several authorities from other fields, acting

[50] It should be noted that the number of high-quality rejected proposals is quite low, which might obscure statistically significant conclusions about the instrument. However, extensive monitoring of both groups may provide much information on the effectiveness of the instrument.

[51] We do not discuss the IOPs, innovation-driven research programs (total budget of about 15 million euro per year). An IOP is established for four to eight years, and covers a theme considered important to business and innovation. The theme is chosen by a steering committee consisting of both public and private stakeholders. Some other policy instruments discussed in the current section also have a selection procedure with public and private stakeholders.

[52] STW is funded by NWO (60%) and the Ministry of Economics Affairs (40%) (STW, 2003).

as laymen to the field under consideration. The jury makes a judgement by comparing 15 to 20 research proposals per round.

Each awarded research project is monitored by a so-called users committee (UC). This committee consists of several stakeholders from business, non-profit organisations, government and research organisations. The committee in principle meets twice a year to discuss the results and progress of the research project. UC membership is free of charge as long as the requested research costs of a project remain below 0.5 million euro. When this margin is exceeded, STW demands a financial contribution from the UC members, which can be provided in kind. In 2003, 30% of the projects exceeded the 0.5 million euro margin (STW, 2003).[53] UC members have no exclusive right to commercialise the obtained research results. If a private party wants exclusive membership in a UC (and thereby the right to exclusive information), a substantial contribution to the project costs is required. For the acquirement of intellectual property rights, STW applies other regulations (See section 6.2).

The effectiveness of STW as an instrument for stimulating technology transfer by improving the match between public and private research agendas cannot easily be established. STW (2002, 2003) reports various indicators, ranging from scientific output (i.e. publications) to patent applications and spin-offs. The involvement of firms is apparently strengthened by the presence of the users committee, and other indicators seem to indicate that STW projects are more successful than projects of other NWO divisions. However, it is unclear whether projects would have been implemented without the STW subsidy, and whether in that case technology transfer would have played an equal role. Also, because technology transfer is an explicit criterion in the referee process, the rewarded programs have good technology transfer capabilities to begin with.

Bsik: Subsidies for investments in the knowledge infrastructure

In 1994, the Dutch government founded the 'Interdepartmental Committee Economic Structure reinforcement' (ICES) to stimulate investment projects to strengthen the Dutch economy. A special working-group named ICES/KIS focuses on the knowledge infrastructure (KIS). In 1994, the first investment impulse (ICES/KIS-1) in the knowledge infrastructure was made, amounting to 113 million euro. The ICES/KIS-2 followed in 1998 (211 million euro). In 2000, a third tender procedure was initiated (ICES/KIS-3). The final decision on investment in this round, known as the Bsik, led to an impulse with approximately 800 million euro for 8 years. The Bsik has several objectives, the most important being to stimulate fundamental strategic and industrial research, and to initiate long-term research collaborations and networks.

[53] It would be interesting to investigate whether this margin elicits any strategic behaviour by private investors. Applicants might decide to reduce (or split up) project proposals to secure free UC-membership. Unfortunately, data on individual project proposals are not available.

The ICES/KIS-3 consisted of three phases, designed to obtain focus in research themes and to select those projects which were economically[54] and scientifically the most promising. In the initial phase (2000-2001), representatives from business and science were invited to propose research areas suitable for a Bsik-impulse. Eight knowledge themes resulted. In the second phase (2001-2002), the business and science community could propose research projects within these eight themes. This ‘call for expression of interest’ resulted in 130 proposals. CPB, among others, advised on the general quality of these proposals at the theme-level. Eventually, five themes were selected, namely ICT, spatial research, durable innovation systems, microsystems and nanotechnology, and health, food, gene- and biotechnology.

In the final phase (2002-2003), a call for proposals within the five themes was organised. A committee of wise men advised the government on which projects to award and to what amount. The committee obtained its information from the Royal Netherlands Academy for Arts and Sciences (KNAW), SenterNovem[55], and Dutch policy research institutes under the co-ordination of CPB. These organisations were asked to evaluate the proposals on different criteria, based on their own expertise. In short, the KNAW was asked to referee the scientific contents of the proposals. The policy research institutes assessed the legitimacy, social benefits, and risk profiles of the proposals, keeping in mind the necessity of a public investment to secure social benefits. SenterNovem mainly evaluated the finance structure and monitored the correctness of the procedures. These various viewpoints facilitated a broad ex ante assessment of the scientific, socio-economic and practical quality of the proposals. In the end, 37 projects received a Bsik subsidy. This extensive referee process was quite unique for the Netherlands, although STW and ICES/KIS-2 already made use of socio-economic criteria in the review process. However, the involvement of the policy research institutions was new.

The Bsik has only been operational for one year, but the program offers a number of opportunities to improve the match between public and private research agendas. To improve commitment, the Bsik requires that each research collaboration would match the Bsik subsidy by an equal amount. A danger is that this might constrain public institutions in their financial capacity (see Box on matching). Furthermore, the collaborations have to consist of both private and public partners (preferably nationally located). However, CPB et al. (2003) find that the contribution of the private sector per project was on average less than 20% of total costs. Most projects appealed to the maximum Bsik subsidy of 50% of total costs. The remaining 30% was received via other public means including first and second flow funding, academic hospital funds etc. CPB et al. (2003) question whether these percentages reflect the ratio between social and private benefits. Finally, the various projects have received large subsidies for a long period of time, i.e. four to six years. Although a midterm-review will evaluate the projects, continuation of the subsidy is not contingent on the outcome of this evaluation in practice. The

[54] In terms of expected social returns in excess of private returns.

[55] SenterNovem is an agency of the Ministry of Economic Affairs.

so-called 'Temporary Committee Infrastructural Projects'[56] recently proposed to introduce outcome-contingent subsidisation in case of long-term and substantial subsidies.

IS: The innovation subsidy for collaboration projects

The Innovation Subsidy (IS), started in 2004,[57] is a subsidy to a private company for a research and development project conducted in collaboration with either a public research institution or another private company. The IS had a budget of nearly 100 million euro in 2004. Normally, IS grants cover between 25% and 50% of the project costs. When the project is carried out in collaboration with a public research institute, or when the firm is a small or medium-sized enterprise, the requesting private company receives an additional 10% subsidy. SenterNovem subscribes four tenders a year. The submitted research proposals are assessed on four equally weighted criteria, namely collaboration (with a Dutch or foreign partner), technological innovation (where fundamental breakthroughs are valued higher than marginal technological improvements), sustainability (including the ecological and social aspects of the project), and the economic perspectives in terms of returns on investment.

Little can be said about the effectiveness of the IS scheme, as it has started just recently and because data on observed differences between rewarded and rejected projects is not available. Although research collaborations are allowed to consist of only private companies, most collaborations have partnerships with a public research organisation: 82% of the granted IS proposals include at least both a private company and a public research institution (EZ, 2004b). However, these data provide no information on the additionality of the IS scheme. Did the IS scheme result in research collaborations that otherwise would not have been initiated? Comparison of evaluation data on both granted and rejected R&D project proposals might help answering these questions.

[56] This committee was installed in 2004 by the Dutch Lower Chamber to develop a framework to monitor long term large scale infrastructural projects.
[57] The IS program replaced some other subsidy schemes.

Matching: A blessing or a curse?

Matching is often feared to impose a constraint on the financial and research freedom of universities (AWT, 2004), but this appears not to be an established fact (CPB, 2004). Matching means that universities partly use first flow or core funding to finance a part of the costs of research projects in the second and third funding flow. These projects, which are subsidised by schemes such as the Bsik, require that part of the funding of the subsidised project is raised by the applicant himself. From an economic perspective, such matching results in an incentive for researchers to deliver high-quality research by financially contributing to the project themselves. From a scientific perspective, though, matching might restrict the academic freedom of the researcher. This is at odds with the principle behind the first funding flow.

AWT (2004) reports that universities experience a matching pressure of about 84% in 2002, which means that for each euro of second or third flow funding the university pays 84 eurocent from its core funding. In total this comprised about half of the universities' core funding in 2002. AWT (2004) concludes that this matching pressure is likely to restrict universities in their choice of research topics. Furthermore, the research agenda tends to become dominated by innovation-steered research at the cost of other types of research (e.g. on society and culture). Finally, the matching pressure affects the investment capabilities of universities.

A contra-expertise study by CPB (2004) states that universities are free to say no to projects which would yield too much matching pressure. Furthermore, the CPB considers the AWT conclusions too sensitive to the implicit assumption that researchers have hardly no scientific freedom in the implementation of a subsidised project in the second or third funding flow. In a sensitivity analysis, the CPB finds that if it is assumed that research freedom in subsidised research is half of that in the first funding flow, then matching does not affect the investment capacity of universities. In case that researchers' freedom in subsidised research would correspond to 75% of the researchers' first flow freedom, the investment capacity of universities would even increase by 35%, as the subsidised research adds to the first funding flow. Furthermore, the AWT analysis includes no scale benefits from subsidised research, which are nevertheless likely to occur in infrastructural investments, e.g. computers or laboratory equipment. Finally, AWT (2004) states that the financing structure of universities should be changed to avoid matching problems, but CPB (2004) questions whether the AWT study sufficiently demonstrated that universities are regularly matching research with no public scientific interest with public funding. But the CPB subscribes the AWT viewpoint that matching should only occur in case of research projects serving a social objective. Furthermore, university boards should set priorities concerning research topics and clearly formulate the criteria for the allocation of first flow funding resources.

The Top Technological Institutes

Four Leading or Top Technological Institutes (TTIs), established in 1997, form largely virtual hubs between public research institutions, universities and the business sector. These four institutes are the Telematica Institute (TI), the Wageningen Centre for Food Sciences (WCFS), the Netherlands Institute for Metals Research (NIMR) and the Dutch Polymer Institute (DPI). Together, they comprise a public budget of approximately 25 million euro per year.

The institutes are oriented towards longer term industry-relevant research in specific areas. They emerged from a competitive selection process, with nineteen proposals for research themes. The selection criteria were utilisation of current research strength, opportunity for substantial scientific progress, and reliance on a solid industrial base (OECD, 2004). To ensure anchoring and commitment of the business community, the government required that private partners significantly contribute to the TTI budget.

Although OECD (2004) values the TTIs highly, it is again difficult to say anything on the additionality of this policy instrument. OECD (2004, p. 5) concludes that the TTIs are “a proven good practice in mobilizing public and private research towards common objectives of high importance for the economy and society”. However, no convincing empirical evidence on the performance of these organisations is presented, and more research will be necessary.

6.5 Absorptive capacity: WBSO, TNO and GTIs

Policies to improve the absorption capacity can follow two approaches. First, policy can aim to increase the absorptive capacity of a firm by stimulating the firm’s own R&D efforts. An example is the WBSO, a Dutch research subsidy program for firms. Second, policy can make in-house absorptive capacity less necessary by creating intermediate institutes which translate scientific knowledge into directly applicable solutions. Main Dutch institutes are TNO and the Large or Great Technology Institutes (GTIs).

WBSO: A wage tax credit for R&D labour

The WBSO, introduced in 1994, is basically a wage tax credit for R&D labour, and directed at stimulating product development or fundamental research within companies.[58] It is the most important subsidy instrument for business R&D in the Netherlands, with a budget of about 367 million euro in 2004.

The WBSO offers a reduction of the R&D wage costs via a marginal tax scheme. Firms are entitled to a refund of 42% of the first 110,000 euro R&D wage costs and 14% of the remainder. For technostarters the first stage percentage is even higher, i.e. 60% (SenterNovem, 2005a). To be eligible, the research project should be executed by the requesting firm within the Netherlands, should develop technology that is new to the firm, so not specifically new to the market, and should have the character of scientific research or product development. The WBSO reaches many firms in the target group. About three quarters of all firms with R&D activity in the Netherlands submitted R&D project proposals for a WBSO subsidy in the period 1996-1998 (Brouwer et al., 2002).

Additional R&D activity may increase the firms’ absorptive capacity through increased R&D activities. However, the evidence on additionality of the WBSO is rather thin, and even less is known about its effect on absorptive capacity. Brouwer et al. (2002) find that independent of the firms’ size or sector, the WBSO subsidy is fully used as additional funding for new R&D. That is, the WBSO subsidy is not applied to finance R&D projects which would have been conducted by the firm anyhow. This estimate is not undisputed. First, Bureau Bartels (1998)

[58] The abbreviation WBSO stands for ‘Wet vermindering afdracht loonBelasting en premie volksverzekeringen, onderdeel Speur- en Ontwikkelingswerk’ (in English: Reduction of Contributions Wage Taxes and Social Insurance Act, Part Research and Development).

find that only 67% of the WBSO subsidy was spent on additional research. Perhaps this latter estimate is more reliable, as the researchers attempt to take account of fungibility (see Box). This estimate should be seen as an upper limit, as respondents tend to give desired answers. Second, Brouwer et al. (2002) use instrumental variables (IV), and the quality of the instruments used are somewhat disputable, so that the results should be interpreted with care.

Brouwer et al. (2002) find in their survey that smaller firms more often indicate that they would not have conducted the research (or would have scaled down the R&D project) without the WBSO subsidy. Smaller firms also expect that their innovation output would have been lower without the WBSO support. From these results we might argue that small firms benefit the most from the WBSO. This is not surprising, as small firms typically receive a larger subsidy (in percent) on their R&D wage costs. However, we do not know whether the WBSO has contributed to their absorptive capacity or only to product development. On the one hand it seems more likely that small firms focus on product development. On the other hand, small firms state that the WBSO subsidy leads to investments in more risky R&D projects, possibly indicating an increase in their absorptive capacity.[59]

Additionality of the WBSO probably overestimated

Cornet (2001) lists three arguments why additional R&D spending via the WBSO subsidy may be an overestimation of extra R&D activity induced by this subsidy:

- Addition: Would the extra R&D spending have been done without the subsidy?
- Fungibility: Are firms labelling activities as R&D which they would not have labelled as such without the subsidy?
- Input price effect: Would the subsidy lead to higher input prices? In other words, will scarce R&D workers increase their wages (thus consuming part of the subsidy), because the demand for researchers is increased by a reduction of R&D costs for firms while supply is largely inelastic (certainly in the short run).

Marey and Borghans (2000) find that 1 euro additional expenditure on business R&D led to a 20 to 30 eurocent raise in wages. The input price effect strongly depends on the elasticity of the labour supply. A large elasticity will positively effect the R&D volume. Cornet (2001) supposes on the basis of the (thin) empirical literature that the fungibility and input price effect jointly account for about one third of additional R&D spending due to the WBSO. Cornet also argues that the WBSO introduces a selection effect. Firms propose the R&D projects which increase their private returns the most, and don't reckon with social returns. A more specific subsidy might be more desirable in this respect.[a]

[a] Obviously, specific support also has its drawbacks. It is beyond the scope of this study to discuss the issue of general versus specific policies into more detail.

[59] An alternative or additional policy instrument to increase the absorptive capacity of small firms is the SKO ('Subsidieregeling Kennisoverdracht Ondernemers MKB'), a subsidy to knowledge transfer for entrepreneurs in SMEs. With SKO subsidy, a highly educated employee can be hired to support the entrepreneur in the implementation of an already chosen technological innovation in his firm. The subsidy per project amounts to 10,000 euro in a full time post for at least one year (the total SKO budget for 2005 amounts to 500,000 euro).

TNO and the GTIs

There are a number of intermediary institutes in the Netherlands which can (partly) provide for the necessary absorptive capacity. These intermediary research organisations constitute a sizeable fraction of the public research infrastructure. The Dutch organisation for applied natural sciences (TNO), the five Great Technological Institutes (GTIs),[60] and the Wageningen University Research (WUR)-institutes together employ a workforce of about 20 per cent of the total research employment in the (semi-)public sector in 2001. Most of these institutes were founded before the Second World War, with the aim to foster the transfer of knowledge from science to industry (e.g., TNO), to stimulate the development of knowledge in new research areas (e.g., ECN), and to increase the application of scientific knowledge important for the Dutch economy.[61]

In contrast to universities, intermediary institutions provide absorptive capacity by applying scientific knowledge in order to articulate industry's demand via contract research (Cornet and Van de Ven, 2004a). However, they do not necessarily act as an intermediary organisation between industry and universities in terms of matching demand and supply. The institutions' research agendas differ from the university research agenda, and even more from the business research agenda (Rensman, 2004). A second potential problem with intermediary institutes is that information is lost in the transfer process between science and industry. Finally, researchers at the institutions have to know what university researchers already know, implying some duplication of efforts.

Recently, the government committee Wijffels scrutinised the current and future role of TNO and the GTIs in the Dutch research market, revealing the following problems in the knowledge transfer between these institutions and partners (Wijffels et al., 2004):

- Inadequate connection with SMEs: SMEs are more regionally oriented. They often appear to be unaware of the institutions' knowledge, and they are not able to articulate their demand;
- Distance to firms and their market: The institutions have too little knowledge of changes in markets and knowledge demand of firms;
- Lack of commitment of private firms: Firms tend to buy concrete products of knowledge development, and are not often involved in longer term research activities of the institutions.

In a reaction to these observations, TNO again focuses more attention to the knowledge transfer to small and medium sized firms. Among others, Syntens (an innovation network) and industry organisations provide platforms for TNO to get in touch with these firms (AWT, 2005).

[60] The GTIs are the Energy Research Centre of the Netherlands (ECN), the Maritime Research Institute Netherlands (MARIN), WL-Delft Hydraulics (WL), GeoDelft, and the National Aerospace Laboratory (NLR).
[61] The HBO-institutions also play a role as intermediaries, particularly for smaller firms (AWT, 2005).

According to Wijffels et al. (2004), TNO and the GTIs should become more market-oriented (market financing), although longer term research should be guaranteed by means of 'taakfinanciering' (task financing). An increasing role of market financing is supposed to force the institutions to match industry's demand. With regard to longer term research, Wijffels et al. (2004) argue that the government has too little expertise to assess the value of research. Therefore public and private stakeholders should be involved early in the choice process on what to finance through task financing. The government should limit itself to process management and monitoring, and not steer in the content of research.

Some crucial elements may hinder the effectiveness of this proposal of the committee Wijffels. Cornet and Van de Ven (2004b) question whether a government that has less expertise than the institutions themselves can monitor and evaluate the outcomes of the transfer process. Can the government determine and articulate what knowledge should be provided by the institutions, when the market fails to develop this knowledge? Furthermore, the role of market financing is hampered by the following factors. The research institutions are impeded by their own history. Some have been founded to do research in certain areas or research for government. The Dutch market might actually be too small for some of these institutions. An additional factor, also mentioned by Wijffels et al. (2004), is that the institutions have to compete with Dutch and foreign universities which might be able to perform research at lower costs.[62] The market could decide to contract its research somewhere else. Both factors might lead to an insufficient or limited realisation of knowledge transfer within the Dutch knowledge infrastructure. On the other hand, the role of TNO is relatively large compared to the role of comparable institutions in other countries. Moreover, Dutch business firms relatively often choose for semi-public research institutions as a source of knowledge rather than universities (Antenbrink et al., 2005).[63]

6.6 Capital provision: TechnoPartner Label and BBMKB

In this section, we discuss TechnoPartner Label and the BBMKB program which are initiated to relax credit market problems for starters.

TechnoPartner Label

TechnoPartner Label provides some sort of certificate to technostarters. TechnoPartner Label is part of the TechnoPartner program discussed in Section 6.3. When applying for a credit technostarters often experience significant difficulties. They have no track record, face uncertain market perspectives, and high initial investments for advanced equipment. TechnoPartner Label provides a kind of second opinion on these technostarters, which might

[62] Wijffels et al. (2004) also note competition on the international market by foreign institutions subsidised by their national governments. However, we do not know to which extent this competition is detrimental for TNO and the GTIs.
[63] Cornet and Van de Ven (2004a) discuss an option to introduce performance-based funding for technology transfer institutes such as TNO.

help in the credit application process. TechnoPartner Label closely cooperates with another EZ instrument, the BBMKB.

BBMKB, a security for credit loans to SMEs

The BBMKB provides security bonds for partial coverage of a credit loan applied for by a small or medium sized company (less than 100 employees).[64] Special conditions are available for securities for starters and innovating companies (SenterNovem, 2005b). Technostarters with a TechnoPartner Label certificate can easily apply for a BBMKB security. The BBMKB has a credit guarantee of about 454 million euro. Credits are typically in the range of 50,000 to 200,000 euro.

This BBMKB program looks promising. The risks experienced by financial institutions when lending to technostarters are significantly reduced. In practice, though, some financial institutions do not consider the TechnoPartner Label a valuable asset when making their credit decisions.[65] Investors appeal to their responsibility to perform ‘good banking’. Suppose a financial investor is uncertain about future cash flow of high-risk technostarters. The BBMKB might reduce the risk for the bank, but the actual risks for the entrepreneur are not reduced. It was this uncertainty in the first place that caused the investor to hold back on the loan. In that case, good banking may imply that a financial organisation protects the entrepreneur from a risky start-up. More often, trustees in bankruptcy point investors to their responsibilities towards entrepreneurs, although it is unclear whether any legal repercussions can result. Finally, we are unclear whether the BBMKB counts for a security reduction in the sense of the Basel II agreement. This agreement entails stricter capital requirements for financial institutions in case of risky investments. When technostarters with a TechnoPartner Label are still considered as high risk, investors might hold back because of solvency considerations. Investors might be reluctant to reserve large solvency buffers for high-risk loans and decide to finance low-risk projects instead.

6.7 Policy instrument mix aimed at science-industry interaction

The total mix of instruments deployed to boost science-industry interaction may reinforce or conflict with each other. Fine-tuning of the instruments within the mix depends on the priorities of policy makers. For instance, when specific barriers in science-industry interaction are considered as important, these barriers may be reduced by an instrument mix which explicitly targets at these specific barriers. Whether the mix is effective depends on the goals of the individual instruments and the organisations involved. Furthermore, the institutional

[64] BBMKB stands for ‘Besluit Borgstelling MKB-kredieten’.

[65] Based on personal communication with an investment manager of a large Dutch bank.

environment interacts with the various instruments. The effectiveness of the policy mix may be reduced if, for instance:

- The goals of the individual instruments and/or organisations conflict with each other;
- There is too much overlap between the instruments or organisations due to historical or institutional rigidities;
- The mix lacks variety in the type of instruments (tax measures, subsidies, risk capital provision, networks etc.);
- There are ad hoc changes in the mix of instruments due to changes in policy priorities.

Moreover, the expected benefits should be compared with the costs of implementation (including the notion of government failure and opportunity costs, i.e. the benefits of other policy instruments such as public support for R&D activity by enterprises). In practice, an evaluation of the policy mix and its effectiveness is very difficult. Such an evaluation requires an analysis of the effectiveness of individual instruments, taking account of the various relevant interactions with other instruments. Policies targeted at reducing one barrier may be ineffective when there remain other serious barriers in science-industry interaction. For instance, promotion of an entrepreneurial culture within academia may not be effective when firms meet difficulties in financing spin-offs.

7 Conclusions

In this study, we investigated science-industry interaction in an economic framework, distinguishing between the public research sector and private companies. Although research in this area is growing rapidly, our understanding of knowledge transfer mechanisms is limited. Firm conclusions can therefore not be drawn, and modesty is in place. This certainly holds for insight into the effectiveness of government policies. Nonetheless, from the theoretical discussion and the practical experiences, we can draw some general lessons and suggest interesting directions for further research. We identified a number of important explanations for suboptimal knowledge transmission from science to industry. In this final chapter we summarise our major findings.

Empirical evidence on science-industry interaction

Science-industry interaction calls for public transmission channels in conjunction with personal contacts

From our empirical investigation of science-industry interaction, we conclude the following. First, cross-country data from the Global Competitiveness Report show that countries with large R&D investments tend to be countries with intensive university-industry research collaboration. The intensity of science-industry interaction also correlates with a number of other indicators of the knowledge economy, such as the quality of public research institutions and intellectual property protection.

Second, science and industry can interact through various channels, and US evidence shows that public channels (such as scientific publications) and private channels (involving personal contacts, e.g. consulting services) are complements. While knowledge transferred through public channels calls for government provision (the market will supply too little as this type of knowledge is non-excludable and non-rival), common economic markets exist for knowledge transmitted through private channels. The challenge for policymakers is to find the right balance between public and private involvement in science-industry interaction programs.

Third, although the US seems to show a somewhat better performance, it is probably an overstatement to talk of a European knowledge paradox. From an inspection of a series of knowledge transfer indicators, we conclude that the Netherlands does not perform systematically better or worse in science-industry interaction than the US, Sweden or Finland. Relatively weak points in the Netherlands refer to cooperation between national universities and the private sector, and the importance of universities and non-academic research institutions as a source of knowledge for the business sector.

Policy interventions, part I: Reducing specific barriers

We considered some policy initiatives to alleviate specific barriers to science-industry knowledge transmission. What are the lessons from these national and international experiences?

Provide direct incentives for scientists to engage in science-industry interaction

In the Netherlands, direct financial incentives for scientists to commercialise their findings hardly exist. Universities can apply for patents in order to obtain the intellectual property rights, but future revenues (e.g. from licenses) may not flow back to the inventor(s). This may explain why Dutch universities produce relatively few patents. However, according to Verspagen (2004), the number of patents produced by universities is much higher when the definition is broadened. This is because in research collaborations the decision to patent is often left to a private partner. For our purpose the former definition is probably more relevant. In the case when patents are the outcome of a joint public-private research effort, knowledge transmission is already secured. To encourage patenting output in the higher education sector, policymakers could consider the introduction of explicit incentives for researchers. The patenting policy of the Dutch Technology Foundation STW provides some reward incentives for researchers, though this is still contingent on the research project. Sceptics point at the pitfalls that financial incentives for scientists interfere with the disclosure of research results and academic freedom, but these worries do not receive robust empirical support.

Provide preconditions for entrepreneurship in academia

Cultural and practical barriers could discourage an entrepreneurial attitude among scientists in the public research sector. While the cultural barrier seems to be reduced, connections with industry are now widely supported in the scientific community, scientists often meet many practical problems when trying to bring their ideas to the market. According to Lazear (2004), specialised skills are more important for scientists while entrepreneurs need to be jacks-of-all-trades. In other words, a professor’s comparative advantage is in science, not in developing new business. Professional guidance and technical assistance of scientists with marketable inventions can help to commercialise public research. Although the US experience with Technology Transfer Offices is not always positive, certain elements are worthwhile to consider in the Dutch context. For instance, TTO-like institutions could support a more professional patent policy in the university sector. Also, the Dutch TechnoPartner program is a promising initiative to encourage the creation of spin-offs from universities and other public research institutions.

Encourage public-private research collaborations to strengthen the match in research activities

Science-industry interaction will be limited when the public and the private sector have different research agendas. A clear economic motivation can be given for such divergence, as certain research areas will be underprovided by the market (i.e. research on health, safety, the environment), so that government provision is necessary. But in situations where there is no strict distinction between the public and private domain, the match between public and private research can be strengthened by improving the institutional climate for joint public-private research proposals. Two important instruments to encourage such joint research efforts in the Netherlands are STW and Bsik. The I/UCRCs in the US and Tekes in Finland are some other examples.

Increase absorptive capacity of private firms

One way to increase a firm's absorptive capacity is to encourage R&D efforts. Policy instruments to increase private R&D investment (tax deduction programs, subsidies, or procurement) may have the side effect that absorptive capacity also increases. The design of the R&D support program may therefore affect science-industry interaction. First, the program may require that the R&D project entails research that is new to the market and not only new to the firm. This increases the chance that the research has close links with new scientific knowledge (although such a policy may be difficult to implement). Second, the R&D program could be made contingent on the size of the firm. Small firms typically have less in-house absorptive capacity (perhaps with the exception of high-tech starters) and meet more difficulties in the capital market. The Dutch WBSO program in its current form is perhaps less suitable to promote absorptive capacity in the sense that the program only requires that the research to be conducted is new to the firm, not specifically new to the market. Also, the WBSO favours technostarters, who already have more intimate connections with the scientific community. On the other hand, the WBSO is more generous for small firms. The question emerges whether government should use specific or generic policies. This will also depend on the causality between R&D and science-industry interaction. When R&D stimulates science-industry collaboration, generic R&D support programs should lead to more intensive public-private research collaboration. When science-industry interaction encourages R&D, more specific elements in public R&D support programs could be desirable (such as additional support when firms collaborate with universities). Alternatively, intermediary public research organisations such as TNO could partly provide for the necessary absorptive capacity, so that firms need not to create this absorptive capacity in-house. Third, and finally, one could increase absorption capacity through mobility of researchers. Firms could get specific knowledge in-house by hiring specialists. As the market should work quite well in this respect, it is not obvious that there is a role for government to encourage mobility of researchers.

Be ‘intelligent’ with venture capital for private firms

Entrepreneurs might encounter difficulties to obtain credit to finance research and development projects. The initiative of TechnoPartner to provide guarantees for investors in high-tech and high-risk new firms is interesting. However, the success or failure of such guarantee system depends on whether the financial sector accepts it or not. Anecdotal evidence suggests that banks may attach little value to such guarantees. There are at least two reasons for this reluctance. First, ‘good banking’ also entails that overinvestment in tricky business is avoided. In fact, banks can be hold accountable when firms enter the twilight zone of a bankruptcy. Second, more stringent solvability requirements are applied when banks invest in more risky firms (the Basel II agreement). The stricter solvency requirements also hold when banks receive guarantees. Summing up, government provision of guarantees may be insufficient to alleviate credit market constraints for high-tech start-ups. Direct public provision of capital could be an alternative, but this raises a host of other questions. It will be particularly hard to defend why the government would have more information on the prospects of a certain investment than the financial sector. Information problems can be reduced by the provision of ‘intelligent’ venture capital (supported by independent experts). An example is the Israeli venture capital program, and an interesting policy option would be to introduce a similar program in the Netherlands. Alternatively, the way pre-competitive financing is designed such as in the SBIR program (with grants only offered in the early research phase, and loans thereafter to correct for credit market imperfections) might be a potential case for an experiment.

Policy interventions, part II: General conclusions

The exploration of the various domestic and foreign instruments reveals that the design of an instrument determines its success, that we need to consider whether the various policy instruments reinforce or weaken each other, and that evaluation studies based on experiments should help to identify the causal impact of policy.

The design of an instrument determines its success

The review of the policy initiatives implemented in the US, Finland, and Israel to remove barriers to science-industry interaction shows that the design of an instrument determines its success. For instance, the US experience with the TTOs has shown that offices with a royalty sharing system are more effective in technology transfer. Also, the SBIR program could be an efficient intervention to foster science-industry interaction in the sense that grants are only awarded in the early phases of development. When the research proceeds, a loan system replaces the provision of grants. Some more general policy reflections concern the role of public programs to encourage private R&D, such as the WBSO. In light of the notion that R&D creates not only innovations but also capacity to absorb knowledge developed elsewhere, such as scientific knowledge, an unintended positive side-effect of R&D support programs is that higher private R&D activity also enables firms to make better use of the public knowledge base. These programs might be designed such that these positive side-effects of R&D are reinforced. Criteria on the innovativeness of the subsidised research and the size and nature of the firm might be considered.

Effectiveness of policy mix remains to be confirmed

In the Netherlands and other countries, a large number of initiatives to promote science-industry interaction have been undertaken, but their joint effectiveness remains to be confirmed. In particular, we need to consider whether the various policy instruments reinforce or weaken each other. At this stage, little is known about such policy interactions. More research on this issue is desirable, as integration of some instruments might be an option. As the analysis of knowledge transmission channels has shown, knowledge is often transferred through a combination of public and private channels. Therefore, in order to promote the connection with the scientific community, one could, for instance, extend the WBSO program with a facility to encourage research collaboration with the public research sector. As we have seen there are already several instruments in place to encourage such research collaborations, and the notion of an optimal policy mix perhaps implies that the set of instruments can be integrated.

Experiments help to identify the causal impact of policy

Reliable ex post evaluation studies on the effectiveness of policies to encourage science-industry interaction are scarce. Insight into the effectiveness of policy could be improved by making sound ex post evaluation an integral element in the process of policy design and implementation. This requires a proper experimental design. (See Cornet and Webbink (2004) for a more elaborate discussion.) One possibility is to use a lottery, but some form of discontinuity in the eligibility criteria can also be exploited (this is done in studies based on natural experiments). For example, the Dutch Innovation Platform randomly allocates vouchers to small and medium-sized firms. These vouchers can be used to finance research contracts with universities and non-academic research institutions. Comparison of the outcomes in the treatment group and the control group can reveal the causal impact of the innovation vouchers (see Cornet et al., 2005). Such experiments help to improve our understanding of the effectiveness of the various instruments.

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