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Differences between Insiders and Outsiders

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Verena Eckl and Dirk Engel*

Benefiting from Publicly Funded Pre-competitive Research – Differences between Insiders and Outsiders

Abstract
This article contributes to the debate on the systemic effects of technology policy by investigating knowledge spillovers of pre-competitive publicly funded Industrial Collective Research (ICR) in Germany. The ICR aims to compensate for obstacles faced by SME in carrying out research and development (R&D). Using data from 911 firms surveyed in 2006, the results show that non-participants use ICR results to a significant extent. However, almost all users in the group of non-participants are engaged in other publicly funded or non-publicly funded collaborative research projects with research institutes affiliated to ICR.

JEL Classification: O38, H59, D21, C25

Keywords: Technology policy Evaluation, public R&D subsidies, pre-competitive research, spillovers

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* Dirk Engel, University of Applied Sciences Stralsund and RWI; Verena Eckl, RWI. – This paper emerged within the context of the Evaluation of the Industrial Collective Research Scheme (Durchführung der erweiterten Erfolgskontrolle beim Programm zur Förderung der Industriellen Gemeinschaftsforschung und -entwicklung (IGF)) conducted by RWI and WSF Kerpen in 2005–2009 financed by the German Federal Ministry of Economics and Technology. Special thanks are expressed to the project leader Bernhard Lageman (RWI) for research guidance and support. We also thank Rainer Graskamp, Joel Stiebale (RWI) and the participants of RENT 2008 Conference for suggestions and discussion on an earlier draft of this paper. A detailed descriptive analysis of the data is found in the IGF project report of RWI/WSF Kerpen (2006). – All correspondence to Verena Eckl, RWI, Hohenzollernstr. 1-3, 45128 Essen, Germany, e-mail: verena.eckl@rwi-essen.de.

1 Introduction

Research and Development (R&D) policy is characterized by a wide range of instruments to address different forms of market failures (Arrow 1963) in the R&D value chain process. Knowledge of the causal impact of these efforts is essential for policy makers to re-design their portfolio of instruments. As David et al. (2000) and many others point out, estimations in the studies reviewed are mostly confronted with potential selection problems. Recently published studies (e.g. Busom 2000, Wallsten 2000, Caloghirou et al. 2001, Lach 2002, Almus and Czarnitzki 2003, Czarnitzki et al. 2007) used state-of-the-art evaluation methods to compare funded firms with comparable non-funded firms. All these studies indicate positive, direct effects of funding on R&D expenditure and patent applications by program participants. This finding speaks in favor of public R&D funding for firms to correct market failure.

In addition to the direct R&D funding for firms, politicians have been demanding improvements in knowledge transfer from science to industry in order to increase the commercialization of scientific discoveries. However, robust empirical evidence concerning the extent of knowledge transfer from science to industry and its determinants for specific programs of public R&D is very rare. The present contribution makes an attempt to investigate the relevance of these effects for Germany's Industrial Collective Research (ICR) program. The ICR program supports pre-competitive research and is one of the most important R&D funding schemes of the Federal Ministry of Economics and Technology. Project themes are developed "bottom up" by firms or research institutes and are supposed to be oriented by definition of the program to the needs of sectoral and even cross-sectoral groups of SME. The pre-competitive research is performed by non-profit research institutes only. However, firms can enter the board of project observers (BPO) (in German "Projektbegleitender Ausschuss") to monitor the project progress. Several studies point out that some imperfections in the knowledge transfer from science to industry exist and firms with high level of R&D activity self-select into R&D programs. Hence, it will be not surprising if program insider outperform program outsider with regard to the use of program results.

Since pre-competitive research does not aim to commercialize brand new ideas, knowledge creation at research institutes and knowledge spillovers to industry are the main benefit of this research. These spillovers are hard to measure. For example, Fogarty et al. (2006) use a systems approach for patent applications and citations to evaluate the

spillovers of the U.S. Advanced Technology Program (ATP). The sophisticated procedure takes cascading sequences of patent citations into account. Within the ICR program, however, firms cannot receive patent protection for discoveries from the program, since research is performed mainly by research institutes. Therefore, we apply a rough measure based on a unique firm survey conducted in 2006 and ask for the use of ICR program results and its determinants.

We will show that ICR research results have been used by both participants and non-participants. Remarkably, almost all non-participants are engaged in other publicly funded or non-publicly funded collaborative research projects with research institutes affiliated to the ICR program. We conclude that these linkages might be a necessary prerequisite for absorbing research results from the ICR program.

The paper is structured as follows. In section 2 we give some background information about the ICR program and derive the main research question. Section 3 presents the methodological approach and section 4 provides the empirical results of our study. Section 5 concludes and discusses the further research.

2 Background

2.1 The ICR scheme

The idea of the Industrial Collective Research (ICR) program was already taken up by the German Ministry of Economic Affairs in the early 1950s. Since 1954, the German Federation of Industrial Research Associations "Otto von Guericke" (AiF) has been commissioned with the project execution of this program. This research program is financed by the Federal Ministry of Economics and Technology. The present annual budget amounts to approximately 101 million euros. About 600 to 700 collective research projects are financed from this budget. The project period averages two years and project costs vary between 50,000 and 350,000 euros (AiF 2005).

The ICR program is characterized as pre-competitive. The verification of "pre-competitiveness" seems to be very difficult. According to ICR guidelines, the conditions for pre-competitiveness are always fulfilled if industry-wide quality standards and regulations are developed or basic research is conducted. Pre-competitiveness is also accepted whenever results are available to all interested firms in the same or other industries and therefore have a "public good" character.

From policy makers' point of view, the main rationale behind public funding of ICR is motivated by the fact that small and medium sized enterprises (SME) are confronted with some specific obstacles[2] in carrying out R&D. SME in the ICR context are defined as firms with an annual turnover below 125 million euros including existing subsidiary and/or parent companies. Following this rationale, the ICR aims at stimulating knowledge creation for SME in particular (AiF 2005:5).

A second rationale behind the ICR is a reduction in duplicated R&D efforts to prepare technical norms and standards, raising health and safety at work, the search for improved or alternative processes or materials, and problems that occur in a sector of industry due to changes in the economic environment (AiF 2005:8). In addition, the obstacle of underinvestment by firms due to spillovers is addressed. R&D spillovers to competitors are difficult to avoid by firms active in R&D and producing spillovers. Projects that generate large knowledge spillovers to competitors are not likely to be performed by the private sector and thus, the private sector tends to under-invest in R&D (see Arrow 1963).[3]

Based on both rationales, and to fulfill the conditions of pre-competitive research, the program seeks to promote the development of industry-wide research networks, which always include SME, large firms and scientific research institutes. In this way, ICR is supposed to support entire sectors of industry and fields of technology in general and SME in particular. From the ministry's point of view, SME have to benefit from each ICR funded collaboration project. In this sense, collaborative activities between SME and large enterprises (LE) are harmless and in line with the principles of ICR if and only if the condition mentioned above is fulfilled. One example of such collaboration is found in the automotive industry where a large company intended to apply 42 Volt vehicle electrical systems (Kobe 1998) and, therefore, suppliers on the downstream value added chain had to test the feasibility of these systems.

The competitive exploitation of results starts after finishing and transferring the project. Then, the enterprises involved – as well as any other firms – may take up the results in

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[2] Those difficulties are, for example, little spread of risk or lack of financial and human resources. For an extensive overview see Nooteboom (1994), pp. 334f.

[3] Griliches (1992) reviewed the literature of R&D spillovers. His study shows that social benefits of R&D may remain significantly above the private benefit of R&D-active firms. He argued, however, that estimates of social return may be upwardly biased.

order to adapt them to their specific needs and build further innovations upon them. Research institutes and associations should take part in the transfer and dissemination of results, using web presentations, publications, conferences, workshops, training of employees, exhibitions or fairs (AiF 2004, 2005; Lageman et al. 1995; Welter 1995).

There are very few ex ante restrictions on the topics of the promoted research projects. Project ideas are ideally developed bottom up by both the firms and research institutions. Enterprises in most industrial sectors and technological fields are "networked" by non-profit industrial research associations. Starting out with 17 industrial research associations in 1954, today 103 of them are united under the umbrella of the AiF with approximately 50,000 firms (SME and LE) and about 700 associated research institutions (AiF 2005). Only the non-profit industrial research associations are authorized to send proposals for funding. Research is typically carried out by non-profit public research institutes.

During the project execution phase, firms and industrial research associations monitor the activities of the research institute. It is necessary for at least two SME to participate in the board of project observers (BPO). Given that ICR is mostly funded by federal government, ICR plans to realize an industry contribution of about 25 % of a project's total research expenditure. It is worth noting that imputed costs are accepted, for example the imputed costs of firms for monitoring the milestones of the research project. However, despite the generous arrangement, 25 % is rarely reached.[4]

Until 2006, public ICR funding was allocated according to the average expenditure of each industrial research association in the last three years. This approach is favorable for associations with large shares in the amount of public R&D funding in the past. In consequence, newly founded research associations are discriminated against. A new agreement was put into force at the beginning of 2007. Only half of all public funding is allocated according to the old procedure while the remaining funding ignores the priorities of specific research associations. The proposals are ranked exclusively on the basis of the evaluation report of external referees (see AiF 2006). The new competitive elements may improve the selection of projects with the highest match to the benefits of ICR and, thus, spillovers of new selected projects may increase.

[4] This statement is based on results of our interviews with representatives of the industrial research associations between 2005 and 2007.

It is worth noting that AiF, the umbrella organization of industrial research associations, also administers other publicly funded R&D programs like the "PROgramme INNOvation Competence" (PRO INNO)[5]. PRO INNO supports national and transnational R&D co-operations between SME or with research institutes if a technology leap (e.g. entrance into a new technology area) or a new co-operation stage (e.g. a foreign partner for the first time) is guaranteed. Additionally, temporary personnel exchanges between enterprises and research institutes are financed, as is the resumption of R&D projects after a five year break. PRO INNO is not pre-competitive, i.e. the research results remain within the enterprise. Furthermore, Pro INNO only supports SME according to the EU definition while the ICR definition is much broader (turnover has to be less than 125 million euros including existing subsidiary and/or parent companies).

2.2 Research question

There are some theoretical and empirical studies on the types of linkages between industry and universities and/or government agencies that depend particularly on incentives and the expectations of players involved (Bonaccorsi and Piccaluga 1994; Etzkowitz 1998; Stephan 1996; Zucker et al. 2002). Other studies deal with the 'absorptive capacity' of firms that stress the importance of internal R&D investments in applying external knowledge (e. g. Cohen and Levinthal 1989, 1990; Kamien and Zang 2000). Last but not least the complexity of knowledge and its role in knowledge transfer is analyzed (e.g. Nonaka et al. 1996). The nature of new knowledge and the characteristics of the knowledge creator act as barriers to knowledge transfer and further efforts are necessary to overcome these limitations. In fact, all the studies emphasize that knowledge transfer between science and industry seems to be a difficult task rather than an easy one. Strong industry-science linkages are advantageous to overcome barriers in knowledge transfer and to absorb scientific knowledge. We assume a "pecking order" in the use of scientific knowledge depending on specific capacities and abilities of knowledge creators as well as knowledge recipients. In this study we shed light on the latter one empirically.

[5] Another public technology program for SME is "Network Management East" (NEMO) that encourages the formation of regional networks of SME and business oriented research institutes in East Germany by the promotion of technologically and economically qualified management services (see http://www.forschungskoop.de/ for further information).

Firms which have been entered the board of project observers may have the easiest access to tacit knowledge created in ICR projects. At the end, firms with lowest level of embeddedness to ICR program may have the lowest propensity to absorb ICR results. In similar manner we also argue size-specific differences in the use of ICR results. Large enterprises (LE) have economies of scale to conduct R&D activities continuously. The competencies and capacity to absorb results are significantly greater than those of SME. In this regard we should not be surprised about a significantly lower propensity of participating SME to use ICR results compared to large companies.

The question about a "pecking order" of the use of external knowledge in this study is directly linked to ICR objectives. While ICR guidelines producing benefits for entire sectors of industry and fields of technology, it appears appropriate to ask about the use of ICR results by participating and non-participating firms. The ICR guideline further points out that SME in particular have to be addressed by ICR. However, the wording "particular use" leaves room for interpretation. One may argue that ICR is working very well whenever participating SME show a higher propensity to use ICR results than participating large companies. In contrast, in the light of some typical SME obstacles to absorbing results we should not be surprised at a significantly lower propensity of participating SME to use ICR results compared to large companies.

3 Methodology

3.1 Measurement of ICR benefits

ICR benefits may exist on several levels. Grimaldi and Tunzelmann (2002, 2003) contribute to the debate on the definition of reliable performance measures of public programs. As expected, subjective evaluation tends to be more optimistic than more objective measures of program outcomes (number of patents, publications, commercial exploitation and follow-up activities). The authors argue that the indicators should be extensively independent of subjective factors and should address all possible positive externalities and benefits for all participants.

The outcomes of a pre-competitive research program are different from those of programs emphasizing commercialization of ideas. Knowledge spillovers are the most relevant benefit of ICR programs. In this sense, patent applications due to ICR participation and their citation by non-participants may be one approach to test empirically the

relevance of knowledge spillovers. For example, Fogarthy et al. (2006) use a systems approach for patent applications and citations to evaluate the knowledge spillovers of the U.S. Advanced Technology Program (ATP).

Indeed, patent applications can be made by industrial research associations and/or research institutes. However, ICR does not focus on patent applications as a main objective because patent applications by their nature may restrain broad knowledge spillovers and conflict to some extent with the pre-competitive assumption of ICR research projects. Thus, patent applications cannot be a yardstick to measure knowledge spillovers from the ICR program. As we ask about the use of research results obtained from ICR, "Have you ever applied ICR research results?" we make a first attempt to shed light on the role of knowledge spillovers.

From a methodological point of view, more precise questions with regard to the context of the use of ICR results would be the best choice. More precision can only be gained at the price of a lower response from firms in general. Thus, the simple question about the use of ICR results should be appropriate to resolve this trade-off. Of course, this measure has some limitations. Generally, it is difficult to evaluate the extent of the usefulness of ICR results for a single firm because the criteria might differ between the firms. In addition, some ICR research results are long-term oriented. In many cases immense efforts are necessary to bring new knowledge to functional model. Probably, firms do not know in the long term that some of the new technologies are created by ICR. Thus, we tend to underestimate the level of use of ICR results.

However, 65% of the firms surveyed in our sample did not answer the above-mentioned question. We checked the response behavior of these firms in detail and detected that 90% of these respondents do not know ICR. Furthermore almost all of them ignored each question in the block concerning participation in ICR. As a result, we re-label non-response to the question as "no use" of ICR research results.

3.2 Knowledge use equation

The equation describing the use of ICR contains the dependent variable Y_i for firm i, which is explained by the vector of exogenous variables X_i. The Bernoulli distributed variable Y_i takes the value one (firm knows ICR) or zero (firm does not know ICR) in the first equation. The probability of the "knowledge of ICR" can be estimated by applying a binary probit model:

$$\Pr(Y_i = 1 \mid X = x_i) = \Phi(x_i'\beta) \quad \forall i = 1,...,N \ . \qquad (1)$$

where Φ_i denotes the cumulative standard normal distribution.

The first set of variables of interest measures the *degree of embeddedness* to an ICR program. Here we define four groups of firms:

(i) participating firms in the board of project observers of ICR research projects (*PARTICIP*),

(ii) firms which are engaged in other research projects with industrial research associations and their research institutes (*AFFIL*),

(iii) individual firms which are members of industrial associations but are not involved in ICR projects (*MEMBERS*), and

(iv) remaining firms (*OUTSIDERS*).

Concerning the *size-specific obstacles* in the use of external knowledge and the aim of the ICR program to support SME in particular, the PARTICIP variable is combined with the status of an SME. PARTICIP_SME contains participating SME and PARTICIP_LE contains large companies involved in publicly funded ICR research projects. The definition of the group of affiliated firms follows two motives. As mentioned above, the AiF manages other publicly funded programs and thus, funded firms in these programs are also affiliated with the research of industrial research associations and institutes to some extent. Secondly, some firms collaborate with industrial research associations in non-publicly funded projects. These firms may also have easier access to ICR results compared to firms without this degree of embededdness.

We expect a ranking of use according to embeddedness in the ICR program and its agents. Due to a lesser absorptive capacity of SME, large participating companies may have the highest propensity to apply ICR research results, followed by participating SME, AFFIL, MEMBERS and OUTSIDERS. Probably, OUTSIDERS are indirectly affiliated with industrial research associations through membership in sector-specific assemblies which are linked to industrial research associations.

One stylized fact of evaluation studies is that participants form a selective group of population. Selection into a program may result from screening procedures derived by program managers and from the income-cost ratio of specific firms participating in a

specific program. Concerning the conception of the ICR program, the attendance of firms is mostly affected by the latter factor.

The pre-selection implies that coefficient estimates do not measure effects of embeddedness in the ICR program only. The estimates are also influenced by observable and unobservable competencies as well as interests in taking part in the program. We will discuss this point in detail in the next section. In order to eliminate biased estimates due to unobserved firm heterogeneity, an instrumental variable (IV) approach will be applied. The implementation of this approach needs to fulfill some restrictive requirements: (a) the instrument variable must be correlated with the explanatory variable, i.e. participation in ICR research projects; (b) the instrument variable must be uncorrelated with the error term in the main equation. We use the two-stage least-squares (2SLS) technique because therefore we are able to combine information from multiple instruments. In the first stage, each endogenous covariate from the main equation is regressed on all valid instruments. In the second stage we estimate the main regression whereby each endogenous covariate is replaced with its approximation of the first stage estimation.

Irrespective of the assumption that participants differ from non-participants, we further assume differences within the group of participants. ICR guidelines impose the obligation to have five SME, defined as firms with less than 125 million euros annual turnover, in large project monitoring boards or at least half of the firms in smaller boards (AiF 2004b:4). Based on the heterogeneous nature of projects (e.g. short-term vs. long-term projects) and the particular interests of SME and large enterprises (e.g. the planned technical solution is not that attractive to SME), it seems to be sometimes difficult to fulfill this requirement. As a matter of fact, the threshold value to define the SME in ICR is more than twice as much as the European Commission's (2003) threshold of 50 million. Maybe, the higher threshold value in ICR may also be an indication of difficulties to fulfill the above mentioned assumption. From these difficulties we assume that selection into the program may differ between SME and large firms. Therefore, we estimate separate IV regression: one for SME and one for large firms.

We further consider a large set of exogenous variables to control for some basic facts of firm's internal and external resources. These resources are:

Firms' internal resources: R&D intensity (R&D expenditure related to turnover, R&D employees related to all employees), innovative sales (turnover with new market products/refined products related to total turnover), number of patents in the last two years, exports (export turnover related to total turnover).

Firms' external resources: informal and formal ways of external knowledge acquisition (universities, customers, suppliers, etc.), R&D co-operations, participation in other research programs, industry, shareholders, the kinds of goods produced by the firm: finished goods only, semi-finished goods & finished goods or semi-finished goods only.

3.3 Data

The analysis is based on a questionnaire survey from 2006. The survey was conducted by RWI Essen and WSF Kerpen in the context of a joint evaluation of the Industrial Collective Research from 2005 to 2009 on behalf of the German Federal Ministry of Economics and Technology. The aim of the sampling procedure was to reach those firms that might be in contact with ICR. Thus the population consists of all manufacturing establishments and some related industries like transportation and R&D-intensive services. With the exception of R&D services and the biotech industry the population contains no micro-firms with less than 2 million turnover per year because it is hardly to be expected that those firms perform R&D. In this stratification we draw 14,000 firm addresses from the AMADEUS database that contains information about 812,583 enterprises with headquarters in Germany.[6]

The data were collected on the basis of a questionnaire in the form of postal interviews. We only received about 911 analyzable responses and hence had a high non-response rate of about 93.5 percent. This high non-response rate may be related with the subject of our questionnaire. Since ICR is hardly well-known, firms might be less motivated to fill in the questionnaire. Thus, we might have a sample selection in our sample that is related to the awareness of ICR. Because the determinants of ICR commitment are the

[6] AMADEUS provides longitudinal data on employment, turnover, 23 balance sheet items and 25 profit and loss account items over a period of up to ten years. Additionally, ownership information (e.g. owner, manager, affiliates), trade descriptions and activity codes (NACE or WZ 2003 and others) and financial information are frequently updated in the database. The data set is collected by the Bureau Van Dijk (BvD), which cooperates in Germany with Creditreform.

topic of this study this kind of sample selection is assessed as positive rather than problematic.

Table 1: Number of firms – different groups

	INSIDER			OUTSIDER	
	PARTICIP	AFFIL	MEMBER	REMAINING FIRMS	ALL
LE	15	27	20	160	222
SME	19	117	10	543	689
SME & LE	34	144	30	703	911

Note: LE: Large enterprise (annual turnover 50 million euros or higher), SME: small and medium-sized enterprises with annual turnover between 2 million and 50 million euros. PARTICP: participating firms in PBO of ICR projects, AFFIL: firms who are engaged in other research projects with industrial research associations and their research institutes, MEMBER: MEMBERS of industrial associations which are not involved in ICR projects, OUT: OUTSIDER firms who are not affiliated with the industrial research associations in any way.

OUTSIDERS (remaining firms that do not have any formal affiliations to the ICR program and ICR authorities) form the largest group in our firm survey. In contrast, firms participating in the ICR program are very rare (see Table 1). The differentiation according to firm size further shows that a large fraction of firms are small and medium-sized ones.

As a matter of fact, we also performed semi-structured face-to-face interviews with twelve out of 103 randomly selected research associations and also randomly selected research projects within those associations in 2006. The subjects of the interviews were the participation of SME, compliance with the pre-competitiveness criterion as well as questions about the project workflow and the industry contribution.

4 Empirical Results

Table 2 shows that 63 of all 911 surveyed firms reported that ICR results affected firm's activities concerning commercialization of results or strengthening R&D activities. ICR results are used by both SME and large enterprises to a significant extent: 39.6% of users in our sample are large enterprises. This finding may emphasize the relevance of the ICR program to industry as a whole, which has been characterized by heterogeneous firm sizes. The share of users related to all surveyed firms lies around 7% and thus, is very small. On the supply side, several barriers as the complexity of knowledge, incentives to codify new knowledge and so on may hamper the diffusion of ICR results. On

the demand side, the mismatch of research efforts of firms and research institutes carrying out ICR research projects may be central to explain the low share of users. Here it is worth noting that 28% of non-users in the group of non-participants are R&D intensive firms with a ratio of R&D expenditures to turnover above 3.5%. In absolute terms, 233 firms are R&D intensive but did not attend the board of project observers and these firms did not use ICR results. From this it follows that the ratio of potential users in the group of non-participants and users in the group of non-participants exceeds five. One further reason for the low number of users might be missing linkages of firms to ICR authorities. Concerning the degree of embeddedness to ICR program, a minority of users (17 of 63) were embedded directly in project monitoring of ICR while more than half of users were affiliated firms (33 of 63). Two-thirds of them received public funding from other research programs which have been phased out by the umbrella organization of industrial research associations and classified as industry-science collaborative research projects. The remaining ones are engaged in non-funded research projects with industrial research associations. Ten of 63 users are firms outside ICR participation, affiliation or direct membership. We conclude that existing formal linkages between industry and non-profit research institutes seem to be the basic prerequisite of non-participants to absorb ICR results. It is not surprising that the share of users is highest in the group of participants (see Table 2). More than half of the participating firms reported that they applied ICR results. Accordingly there is a high number of participating firms that did not use ICR results. The reason might be that ICR focuses on pre-competitive research, and thus the probability of project breaks, adjustment of time schedules and project targets or project cancellation is higher than in follow-on research and its commercialization. Our interviews with ICR representatives showed that there are many reasons for this observation. Changes in legislation, dropouts of firms, long-term research efforts and technical difficulties were the most frequently mentioned ones. The recent implementation of competitive elements in the selection process strengthens a “pick the winner” strategy. Probably, the overall benefits of the ICR program may increase in the future.

As expected, the share of users decreases with ICR embeddedness. 23% of affiliated firms and 1.4% of outsiders are users of ICR results in our sample. Obviously, affiliation may enhance the access to ICR results. Affiliated large enterprises (LE) use ICR research results significantly more frequently than affiliated SME. In contrast to that,

the share of users differs only very slightly according to firm size in the group of outsiders.

Table 2: The use of ICR results

	PARTICIP	AFFIL	MEMBER	OUT	ALL
	Number of users				
LE (user)	8	12	3	2	25
SME (user)	9	21	0	8	38
LE +SME (user)	17	33	3	10	63
	Share of users in all firms of the group (in %)				
LE (user)	53.3	44.4	15.0	1.3	11.3
SME (user)	47.4	17.9	0.0	1.5	5.5
LE+SME (user)	50.0	22.9	10.0	1.4	6.9

Note: See notes to Table 1.

Probably, group differences in the propensity to use ICR results are based on differences in other characteristics like industrial affiliation and R&D activity. Applying a binomial probit model we take these characteristics into account and test for significant differences between the four groups (Table 3).

The observed pattern for the different groups also holds in the multivariate analysis. Since the share of users is very similar between participating SME and participating LE, the coefficient estimates for indicator variables do not differ significantly between the two groups. Only with the assumption that SME and LE are pre-selected into the program in a similar manner, the result may indicate that participating SME benefit to a similar extent from ICR as participating LE. As pointed out in the section before, a further regression is necessary to eliminate biases due to different selection procedures in the ICR program.

In line with descriptive findings, affiliated LE have a significantly higher share in the use of ICR results than affiliated SME. Following the argument of absorptive capacity, large enterprises may have some advantages in absorbing ICR results and commercializing them. Furthermore, the result may highlight that affiliated SME are more oriented to the commercialization of research ideas and thus, these firms are less interested in results of pre-competitive research than larger companies.

Table 3: Coefficient estimates of Binomial Probit Model
(1=use of ICR results, 0=otherwise)

Variables	All firms	SME only	LE only
PARTICIP_SME	1.346***	1.536***	
	(0.395)	(0.486)	
PARTICIP_LE	1.397**		1.244***
	(0.457)		(0.451)
AFFIL_SME	0.847***	0.903***	
	(0.195)	(0.234)	
AFFIL_LE	1.503***		1.438***
	(0.305)		(0.334)
MEMBERS	0.152	-0.302	0.370
	(0.288)	(0.485)	(0.377)
R&D Target: process development	0.363**	0.367*	0.298
	(0.173)	(0.214)	(0.336)
R&D Target: New markets	0.301**	0.370*	-0.104
	(0.173)	(0.209)	(0.302)
Formal knowledge use: Non-profit research institutes	0.500	0.510**	0.641*
	(0.182)	(0.232)	(0.342)
Shareholder impact on business activity	$3.62e^{-06}$***	0.004	$2.98e^{-06}$
	($9.60e^{-06}$)	(0.009)	($1.05e^{-05}$)
Patents	0.354	0.733**	0.037
	(0.240)	(0.362)	(0.363)
Manufacturing Sector	0.081	0.327	-0.236
	(0.197)	(0.250)	(0.295)
R&D to turnover ratio (%)	0.219	0.175	0.124
	(0.175)	(0.230)	(0.351)
(R&D to turnover ratio (%))²	0.043***	0.061***	0.365**
	(0.019)	(0.022)	(0.184)
Constant	-0.001***	-0.001***	-0.044**
	($3.82E^{-04}$)	(4.40E-04)	(0.019)
$\beta_{PARTICIP\ LE} = \beta_{PARTICIP\ SME}$	0.01	/	/
$\beta_{PARTICIP\ LE} = \beta_{AFFIL\ LE}$	0.04	/	/
$\beta_{PARTICIP\ SME} = \beta_{AFFIL\ SME}$	1.23	1.32	/
$\beta_{AFFIL\ LE} = \beta_{AFFIL\ SME}$	4.32**	/	0.14
Pseudo R^2	0.383	0.392	0.425
No. of observations	887	673	214

Note: See notes to Table 1. Heteroscedastic-robust standard errors are derived. *** significant at 1% level,** significant at 5% level, * significant at 10% level. Reference group: OUTSIDERS.

Affiliated LE do not differ significantly from participating LE. In contrast to this finding, participating SME outperform affiliated SME with regard to the use of ICR results. The findings indicate that effects of negative selection due to the obligatory presence of SME are compensated for by positive effects of program embeddedness and preselection of SME with above average interest into the group of participants.

MEMBERS do not differ from OUTSIDERS with regard to the use of ICR results. On the one hand, membership only apparently may not provide efficient access to ICR results. On the other hand, members may have lower interest in ICR results. Results of

our interviews with industrial research associations emphasize that the latter factor seems to be the most relevant one.

The estimation results clearly suggest a significant positive correlation between the use of ICR results and a strong embeddedness in ICR. As a matter of fact, affiliation with research institutes which are engaged in ICR projects seems to be sufficient to participate in the ICR program.

The other significant characteristics are mentioned briefly. Participation in the manufacturing sector as well as R&D intensity correlates positively with the absorption of ICR results. The turning point of R&D intensity is reached at an R&D ratio of 24% (R&D expenditure to turnover in %). Furthermore, SME with industrial shareholders also have a higher propensity to use ICR results.

Concerning the assumption of selection into the ICR program, we present the results of the instrumental variable (IV) approach in Table 4. We expect that the supply of relevant scientists in the surroundings of the individual firm will enhance the creation of formal and informal cooperation between firms and public research. From a theoretical point of view, density of scientists should not guarantee that ICR results are used to a higher extent. In the first step, we tried a number of instrument variables to check the validity of IV requirements, namely the assumption of the relevance and the suitability of the IV approach:

- Number of ICR research associations (different radiuses)
- Number of ICR research institutes (different radiuses)
- Number of acquired third-party-funds per district and within a radius of 50 km
- Number of university researchers in terms of engineers and natural scientists within a district and within a radius of 50 km

However, only the variable *number of university funded engineers within the district of firm's location* shows significant correlation with participation state. This variable forces the collaboration between research institutes and industry in both the SME and the LE regression. Irrespective of the significance of the instrument variable in first stage estimation, the empirical tests differ remarkably in the SME and LE regressions. The empirical F-test shows values around the critical value of 10 in the regression for LE, which is usually accepted for significant correlation. An additional test statistic to

evaluate the relevance of instruments is Shea's (1997) first stage partial R^2 of excluded instruments. This statistic also confirms the validity of the chosen instruments in the LE regression. Compared to that, the IV estimation for SME may suffer from some limitations. Empirical F-test and partial R^2 are remarkably lower and below the critical values. For SME we cannot rule out the fact that the IV approach might suffer from inconsistencies due to weak instruments (see Bound et al. 1995).

Table 4: Coefficient estimates of Instrument Variable Approach (1=use of ICR results, 0=otherwise)

Variables	2SLS for SME	2SLS for LE
PARTICIP	0.679	1.205***
	(0.555)	(0.462)
R&D Target: Process development	0.049**	-0.023
	(0.022)	(0.056)
R&D Target: New markets	0.007	0.026
	(0.019)	(0.056)
Formal knowledge use: Non-profit research institutes	0.071***	0.073
	(0.024)	(0.081)
Shareholder impact on business activity	0.019	-0.085*
	(0.029)	(0.052)
Patents	0.015	0.033
	(0.880)	(0.058)
Manufacturing Sector	0.021	-0.004
	(0.029)	(0.059)
R&D to turnover ratio (%)	0.005*	-0.000
	(0.003)	(0.009)
(R&D to turnover ratio (%))^2	$-4.39e^{-5}$ *	$3.25e^{-5}$
	($1.99e^{-5}$)	($6.80e^{-5}$)
Constant	-0.035	0.404***
	(0.022)	(0.058)
Partial R^2	0.008	0.0453
F (1)	5.33	9.54
No. of observations	670[#]	211[#]

Note: See notes to Table 1. *** significant at 1% level,** significant at 5% level, * significant at 10% level. Instrument Variable: *Number of university funded engineers in the district of firm' location.* The results for the first stage regressions can be obtained from the authors on request. Hansen J statistic as well as Sargan statistic to check the suitability of IV approach are not funded by reason of taking one instrument only. [#] Different No. of observations results from the fact that six enterprises did not have postcodes to merge successfully with our IV.

The results of the instrument variable approach at least confirm the results for large enterprises (LE). Therefore we now have a rather unbiased significant positive effect of participation in ICR project performance for LE. The coefficient reaches 1.205 and is almost as high as the interaction effect for participating LE (PARTICIP_LE) in Table 3. The small difference further suggests that the upward bias due to unobservable factors is low. Since the IV approach failed for SME we assume that there are hitherto unob-

served differences between participating SME and LE. At this point we can only speculate whether the upward bias is similar for SME.

As we compare the means of important characteristics between participating LE and SME, we briefly shed light on the question why IV does not work for SME (see Table 5). Remarkably, both the R&D turnover share and the R&D personnel share of participating SME are twice as much as for participating LE. Furthermore, we detect no significant differences with respect to the shares of academics, new and refined products and the share of firms with at least one patent application. These results indicate no differences in the absorptive capacity of participating SME and LE. However, major differences may exist in the use of external resources to prepare R&D. Formal external information sources as well as co-operations are significantly less important for participating SME than for participating LE. Consequently, university orientation toward third-party funding at the firm's location is less advantageous for SME than for LE. Maybe this empirical observation explains the failed IV approach with respect to the use of ICR results by SME. There must be other unobservable reasons for SME to join ICR project management that have to be subject of future research. However, we can speculate on the background of our interviews with the executives of research institutes and associations. On the one hand SME may try to get in contact with LE in order to gain potential new customers. On the other hand LE may want to involve their suppliers in ICR project monitoring due to the ICR guidelines obligation to include at least two SME, or because the supplier's knowledge can contribute to ICR project execution.

Table 5: Comparison of participating LE and SME

Means of Variables and significance						
Variable	LE	SME		Variable	LE	SME	
Source of information				Vertical	0.667	0.526	
Sectoral association	0.600	0.263	**	Horizontal	0.533	0.158	**
Chamber of commerce	0.267	0.053	*	High-Tech Joint Ventures	0.200	0.000	**
Institute of business develop.	0.333	0.263		Public research associations	0.600	0.368	
Univ. tech. transfer offices	0.400	0.368		Other formal utilization	0.000	0.000	
Exhibitions	0.733	0.842		**Industry**			
Conferences/Workshops	1.000	0.789	*	MF of foods & beverages	0.000	0.053	
Journals	0.800	0.789		MF of textiles and leather	0.000	0.053	
Face to face contact	0.467	0.368		MF of wood and paper	0.000	0.105	
Supplier & Customer	0.867	1.000		MF of chemicals	0.067	0.158	
Consulting Agency	0.133	0.158		MF of biotechnology	0.067	0.105	
Internet	0.533	0.579		MF of machinery	0.267	0.105	
Other sources of information	0.067	0.053		MF of transport equipment	0.133	0.053	
R&D targets				MF of metals	0.200	0.211	
Product refinement	0.800	0.789		MF of rubber, plastic, glass	0.000	0.053	
Product development	0.933	0.737		MF of elect. & optical eqpt.	0.067	0.158	
Open new markets	0.733	0.579		MF other	0.000	0.000	
Process refinement	0.800	0.421	**	Elec., gas & water supply	0.667	0.000	
Process development	0.667	0.368	*	Transport, storage & com.	0.000	0.000	
Standardization	0.400	0.211		Real estate and business	0.133	0.000	
Conservation of nature	0.467	0.158	*	Other business activities	0.000	0.000	
Quality improvement	0.667	0.632		Research and development	0.667	0.000	
Rationalization	0.600	0.579		**Impact on business activity**	0.555	0.188	**
Other targets	0.000	0.000		**Turnover (in millions)**	7947	14	
Cooperation Partners				**Type of goods**			
Horizontal	0.533	0.188	**	Semi & finished goods.	0.313	0.250	
Vertical	0.733	0.313	**	Semi-finished goods	0.438	0.250	
With universities	0.800	0.438	**	Finished goods	0.500	0.250	
Other research institutes	0.467	0.250		**Shares % (in 2005)**			
With applied universities	0.000	0.125		Exports	58.27	35.17	**
Other partners	0.267	0.063		Refined products	20.00	20.62	
Inf. use of ext. knowledge				New products	16.67	13.53	
Horizontal	0.933	0.895		New market products	3.33	7.57	
Vertical	0.667	0.474		University graduates	16.38	16.90	
With (applied) universities	0.733	0.632		R&D employees	5.00	10.14	
Other research institutes	0.467	0.632		R&D turnover	2.54	9.19	**
Institute of business develop.	0.267	0.316		**Patents**			
Sectoral association	0.467	0.211		Patents (yes/no)	0.667	0.500	
Chamber of commerce	0.200	0.053		Number of patents	139	2	
Formal use of ext. knowledge							
License ordering	0.200	0.053					
Universities	0.600	0.368					
Applied universities	0.267	0.263					

Note: See notes to Table 1. RWI Essen/WSF Questionnaire Survey 2006, own calculations. ** significant at the 5% level; * significant at the 10% level. Number of observations: 887.

5 Conclusion and further research

This contribution presented empirical evidence regarding the extent and determinants of knowledge transfer from science to industry for Germany's Industrial Collective Research (ICR) program. Within the ICR program industrial research associations initiate publicly funded research projects which are carried out by non-profit oriented research institutes and each project has to be monitored by several firms in the board of project observers.

Based on unique firm data surveyed in 2006, we detected that 63 of 911 firms answered that they used ICR results. The majority of users denied the question to be present at the board of project observers. Asking for key competencies to absorb ICR results, three quarters of non-participants answered to be affiliated to industrial research associations due to formal co-operation in otherwise publicly or privately funded research projects. In the sample of the remaining 25%, firms with linkages to university research institutes show a significantly higher propensity to use ICR results than firms without those linkages. Based on these findings we draw the conclusion that existing formal linkages between industry and non-profit research institutes seems to be the basic prerequisite of non-participants to absorb ICR results. Our multivariate analysis strengthened this conclusion and further suggested a pecking order in the use of ICR results: The stronger the linkages to ICR actors the higher the propensity to use the ICR results is.

Indeed the diffusion of ICR results to non-participants works, but is limited to a specific group of firms. Apart from that, the share of users related to all surveyed firms lies around 7% and therefore, is very small. It is worth noting that many non-users are R&D intensive firms. These firms form the group of potential users which are not attracted by ICR for whatever reasons. Building competencies to enter into collaborative projects and increasing the match between interests of industry and public research may be one central effort for managers and policymakers to enhance the diffusion of ICR results to potential users.

Results of our multivariate analysis further suggest that the propensity to use results did not differ significantly between participating SME and participating LE. Contrary to that, non-participating LE with other linkages to industrial research associations show a significantly higher use of ICR results than SME with similar linkages. Concerning the size-specific obstacles for the absorption of external knowledge, we interpret this find-

ing as evidence for a particular use of participating SME. Within the group of non-participants we fail to derive a similar conclusion for non-participating SME. In general, large enterprises play a key role in pushing technology development via ICR program. It is probable that participation by SME may result of their own accord, as well as at the suggestion of large enterprises. Maybe collaboration between small and large firms is essential to attract SME to program participation, to enter into collaborative projects between industry and science and thus, for the diffusion of ICR results all in all. In our point of view policymakers should not be afraid to accent the central role of LE in order to improve knowledge diffusion.

Further research may emphasize a somewhat more sophisticated measurement of knowledge spillovers from ICR. Our rough measure addressed spillovers of application-oriented results. Asking about specific technologies or long-term effects of ICR funded collaborations may provide a more robust view of knowledge spillovers of the ICR program. The causality between participation in the ICR program and other programs remains of particular interest. Future research should also emphasize the outcomes of specific projects for each partner. This approach may address the specific aim of the ICR program ("particular benefit for SME") better. It might also be that large companies only benefit from ICR results in specific projects, but this cannot be confirmed by our survey data. Probably, differences in quality between industrial associations are expressed partially by industry affiliation variables and correlate with the extent of knowledge diffusion. Last but not least, the question of information about ICR and how it is disseminated warrants further investigation.

Literature

AiF (2006), Vereinbarung über die Aufteilung der Fördermittel für das Programm zur Förderung der Industriellen Gemeinschaftsforschung und -entwicklung (IGF), http://www.aif.de/igf/richtlinie.php [retrieved on 08/08/2008].

AiF (2005) - Arbeitsgemeinschaft industrielle Forschung (Ed.): *English Handbook 2005*, Berlin 2005.

AIF (2004a) - Arbeitsgemeinschaft industrielle Forschung (Ed.): Vereinbarung über das Nachweisverfahren zur Bestimmung der vorhabensbezogenen Aufwendungen (Eigenbeteiligung) der Wirtschaft für das Programm zur Förderung der Industriellen Gemeinschaftsforschung und -entwicklung (IGF), Berlin 2004.

AiF (2004b), Richtlinie über die Förderung der Industriellen Gemeinschaftsforschung und -entwicklung (IGF), http://www.aif.de/igf/richtlinie.php [retrieved on 08/08/2008].

Almus, M. and D. Czarnitzki (2003), The Effects of Public R&D Subsidies on Firms' Innovation Activities: The Case of Eastern Germany. *Journal of Business and Economic Statistics*, 21, 226-236.

Arrow, K. J. (1963), Uncertainty and Welfare Economics of Medical Care. *American Economic Review*, 53, 941-973.

Busom, I. (2000), An Empirical Evaluation of the Effects of R&D Subsidies. *Economics of Innovation and New Technology*, 9, 111-148.

Caloghirou, Y., A. Tsakanikas and N. S. Vonortas (2001), University-Industry Cooperation in the Context of the European Framework Programmes. *Journal of Technology Transfer*, 26, 153-61.

Cohen, W. and D. Levinthal (1990), Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, 35, 128-152.

Czarnitzki, D., B. Ebersberger and A. Fier (2007), The Relationship between R&D Collaboration, Subsidies and R&D performance: Empirical Evidence from Finland and Germany. *Journal of Applied Econometrics*, 22, 1347-1366.

David, P.A., B.H. Hall and A.A. Toole (2000), Is Public R&D a Complement or a Substitute for Private R&D. *Research Policy*, 29, 497-529.

Fogarty, M.S., A. K. Sinha and A. B. Jaffe (2006), ATP and the U.S. Innovation System: A Methodology for Identifying Enabling R&D Spillovers Networks. *NIST GCR 06-895*, National Institute of Standards and Technology, U.S. Department of Commerce.

Griliches, Z. (1992), The Search for R&D Spillovers. *Scandinavian Journal of Economics*, 94, 29-47.

Grimaldi R. and N. von Tunzelmann (2002), Assessing Collaborative, Pre-competitive R&D Projects: The Case of the UK LINK Scheme. *R&D Management*, 32, 165-173.

Grimaldi R. and N. von Tunzelmann (2002), Sectoral Determinants of Performance in Collaborative R&D Projects. *International Journal of Technology Management*, 25, 767-778.

Klette, T.J., J. Møen and Z. Griliches (2000), Do Subsidies to Commercial R&D Reduce Market Failures? Microeconometric Evaluation Studies, *Research Policy*, 29, 471-495.

Kobe, G. (1998), The 42-volt Revolution - Automobile Battery Voltage Increase - Cover Story. *Automotive Industries Magazine*, August.

Lach, S. (2002), Do R&D Subsidies Stimulate or Displace Private R&D? Evidence from Israel. *Journal of Industrial Economics*, 50, 369-390.

Lageman, B., W. Friedrich, M. Koerbel, A. Oberheitmann and F. Welter (1995), Der volkswirtschaftliche Nutzen der industriellen Gemeinschaftsforschung für die mittelständische Industrie. *Untersuchungen des Rheinisch-Westfälischen Instituts für Wirtschaftsforschung*, Heft 15, Essen.

Nooteboom, B. (1994), Innovation and Diffusion in Small Firms: Theory and Practice. *Small Business Economics,* 6, 327-348.

RWI Essen and WSF Kerpen (2006), Erweiterte Erfolgskontrolle beim Programm zur Förderung der IGF im Zeitraum 2005 - 2009, 2. Zwischenbericht, Schwerpunktthema Unternehmensbefragung, http://www.aif.de/igf/esk.php [retrieved on 08/08/2008].

Wallsten, S. J. (2000), The Small Business Innovation Research program: encouraging technological innovation and commercialization in small firms? *Rand Journal of Economics*, 31, 82-100.

Welter, F. (1995), Die industrielle Gemeinschaftsforschung als kooperative Forschungsstrategie für kleine und mittlere Unternehmen. *Internationales Gewerbearchiv*, 43, 47-56.