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Empirical Evidence from Firm-level Panel Data

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Abstract:

In this paper we study the question of the leverage effect of public subsidies to private R&D: do public contributions to private R&D boost total R&D expenditures – and if so, do they boost them by an amount which is larger than the amount of public money which was used in this way? The paper is based on firm-level data from the Austrian Industrial Research Promotion Fund (FFF) which occupies a central role in the promotion of industrial research in Austria. The results of the panel regression suggest that the public subsidies of private R&D has a crowding in effect of about 40 percent; 1 additional euro of funding induces firms to contribute an additional 40 cents of their own money. Both very small and large firms seem to exhibit higher leverage; small and medium-sized firms smaller leverage. Additionally, the leverage estimates for firms that perform R&D only occasionally are higher than for regular R&D performers.

JEL: O32, O 38

Keywords: R&D, Additionality, Government subsidy, Technology Policy

1 Introduction

It is nowadays a well known fact that innovation and research and development (R&D) are important sources of economic growth. The innovative strength of a nation's business sector is thereby one of the key factors of its capacity to compete in the international environment. Among other relevant input factors, private investment in R&D is extremely important for boosting the innovative strengths.

Expenditure on R&D is often considered as an investment in knowledge creation, which can further be translated into new or better products and production technologies. Recent OECD work also points to this issue (*OECD 2003, 2000*): their cross-country empirical analysis shows that it is R&D performed by the business sector which has a significant positive effect on output growth. This thus reinforces a wide range of already existing empirical work at the firm, sectoral and aggregate levels examining the effects of increased R&D activity on productivity (see *Coe and Helpman 1994, Wieser 2001* for an overview). Despite variations in the estimated returns of R&D, they arrive at much the same conclusions: that there is (i) a positive and strong relationship between R&D expenditures and growth of output or total factor productivity respectively and (ii) that R&D leads to the accrual of spillover benefits by other firms.

R&D is thus again high on the policy agenda. The recent EU summits at Lisbon (2000) and Barcelona (2002) have emphasized the importance and the public role of R&D. Policy makers are now aware of the substantial contribution of science and technology to the competitiveness of industries and have thus decided to increase the R&D intensity of the EU from nearly 2 percent in 2000 to 3 percent of GDP by 2010. This target should be reached by a substantial increase of R&D expenditures of the private sector. In the context of the Barcelona target the question arises, how R&D policy can stimulate private R&D activities or to which extent government spending crowds out private money. Hence, the economic rationale for government involvement in the area of R&D expenditure is now – having the 3 percent target in view – at the center of policy concern. This question is by no means new – for years scientists have investigated the relationship and impact of public subsidies on private R&D expenditures. A lot of studies with different methodologies and approaches try to yield some substantial policy implication on this topic. However, the substantial limitation of a policy to subsidize private R&D is due to the fact, that private return on industrial research is a priori higher than the private return on basic research, so that the justification of public subsidies to private R&D is lower than the justification of public funding of (academic) basic research.

Two fields of research have been identified to analyze the linkage between private and public R&D investment. First, there are qualitative analyses, namely case studies, surveys, and peer reviews, which are very expensive if done on a large scale and not well suited for generalization. Second, the group of quantitative microeconomic analysis, which count for microeconomic information on a broad number of companies. These kinds of studies require detailed databases and careful methodological

considerations in order to allow for detailed analysis of the determinants which may have an impact on private R&D activities.

However, policies to stimulate R&D investment levels should ideally be based on an understanding of the dimensions and causes of the problem. This includes the understanding of the changing patterns and incentives of industry to invest in R&D as well as the indication of ways of how public policy can best adapt to the new R&D environments.

Within the OECD activities the working group on innovation and technology (TIP) has applied a broad view on these issues by focusing on new patterns of private and public financing of R&D. The current project on 'Changing patterns of Public and Private Financing of R&D' (OECD 2001) aims to improve cross-country co-ordination of research into two broad issues:

- On the firm level a new restructuring of R&D activities in response to a number of forces, including new technological opportunities and growing competition can be observed over the last decade. The evidence of significantly changing business strategies for R&D has consequences for governments in adopting their policy measures.
- The second part of activities raises the question of the effectiveness of government policy instruments for supporting business innovation. This leads into the 'heart of darkness' and contributes to the intensively discussed questions of whether government R&D funding has a complementary or substitution effect on private R&D investment. Does government funding crowd out private R&D funding completely, partially, or not at all? Are there in fact positive leverage effects observable?

The present study contributes to the second part of activities and thus continues its work of the first phase of the project, which consisted of a review of methodologies and approaches available to provide a quantitative assessment of the impact (in particular of the leverage effect) of public support to private R&D (Gretzmacher *et al.* 2002, OECD 2002).

The report is structured as follows: The first part of the study gives an overview of the changing patterns of public financing of private R&D showing that public funding of private R&D has decreased over the last decade¹). The second part comprises an empirical analysis of effects of public subsidies to private R&D. The analysis is based on the recent evaluation of the Austrian Industrial Research Promotion Fund (FFF) and focuses on the leverage effect of public subsidies on the private R&D expenditures.

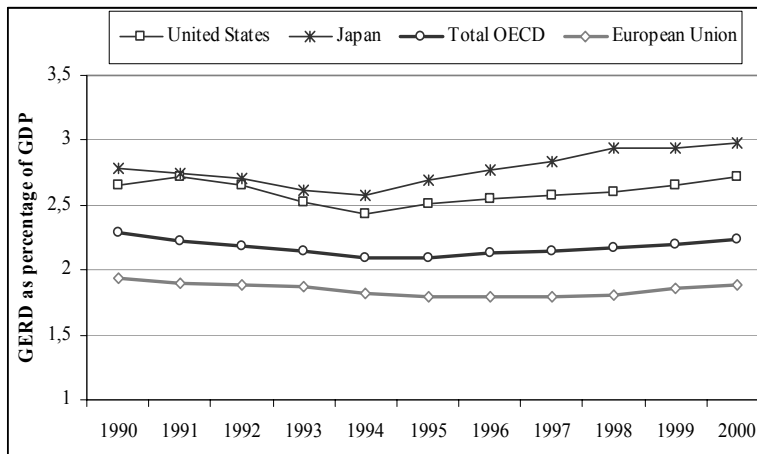
¹) This development was compensated in most countries by the increase of indirect fiscal measures (see *Expert Group* 2003).

1.1 Trends of R&D Expenditures

As was already mentioned above, the summit at Barcelona constituted the formal recognition of the importance of R&D as the main driving force in order to attain the goal of becoming the world's leading knowledge-based economy. R&D was thus fully incorporated into the policy agenda – not as a goal in itself, but as an important contributor to economic welfare.

Before analyzing the effects of public spending on private R&D it is worth – as a first step – asking what have been the major trends in industrial R&D and what implications do these for policy have? To begin with, the following Figure 1 shows the difference in R&D intensity, measured as a percentage of GDP for the period 1990-2000.

Figure 1: GERD as a percentage of GDP



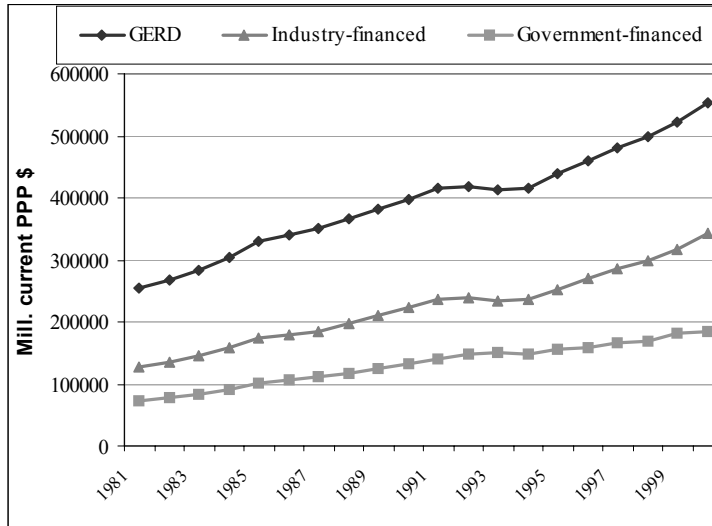
Source: OECD

Figure 1 shows the difference between selected countries as well as the EU and the OECD region. It shows that in the course of the 1990s, the average R&D intensity of the EU has actually fallen; whereas at the start of the decade, R&D expenditure amounted to 1.94 percent of GDP, by 2000 it was down to 1.88 percent, admittedly somewhat higher than the 1.80 percent of the mid-1990s. This slightly U-shaped pattern is not an exclusive characteristic of the EU: the USA and the OECD in general show similar developments, although on a higher level. Hence, R&D spending worldwide slowed for several years in the early and mid-1990s, mainly due to economic recessions and general budgetary constraints that slowed both government and industrial sources of R&D support. However, in the past few years, R&D spending has rebounded in several countries.

The following Figure 2 shows that there has been an upward trend of industrial R&D and thus the increase of Gross Expenditure on R&D in the OECD region was mainly based on the increased growth of business sector R&D in the second half of the 1990s. While

compound annual growth rate of government financed R&D in the period 1994-2000 was 3.6 percent the industry financed R&D grew by 6.4 percent.

Figure 2: Gross Expenditure on R&D in OECD



Source: OECD (MSTI)

This growth rate of industrial R&D was partly fuelled by a large increase in venture capital funding in the USA (*OECD 2001*) though this has declined dramatically from its peak in 2000. A wide range of reasons could explain the increase in industrial R&D (see *Coombs and Georghiou 2002*):

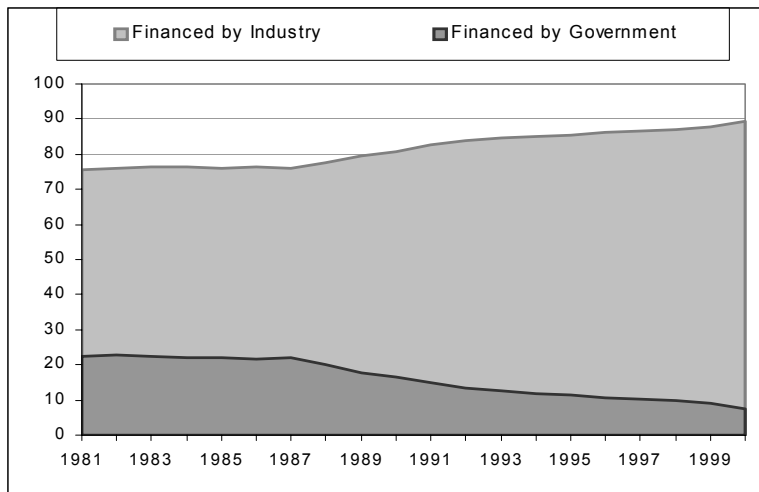
- A wider range of technological opportunities;
- Increases in R&D productivity through availability of new tools and methods;
- Increased competitive pressure to innovate; greater ability to afford R&D in favourable economic conditions; and
- Increased returns from stronger and broader intellectual property rights.

1.1.1 The role of governments in financing business R&D

Most of industrial R&D is provided by industry itself. Government financing accounts for a small and even declining share of the industry R&D performance. This share ranges from less than 2 percent of industry R&D in Japan to nearly 13 percent of Italy's industry R&D effort. Over the last two decades the increase of indirect measures within the many OECD countries partly compensated the decreasing share of direct public funding of industrial R&D. At the beginning of the 1980s nearly 23 percent of industrial R&D in the OECD was financed through public grant or direct measures, respectively. This share decreased to 17 percent in 1990 and exhibit a share of 7.5 percent in 2000.

Part of the relative decline reflects the effects of budgetary constraints, economic pressures, and changing priorities in government funding (especially the relative reduction in defense-related R&D in several of the major R&D-performing countries, notably France, the United Kingdom, and the United States). Another part reflects the absolute growth in industrial R&D funding as a response to increasing international competitive pressures in the marketplace, irrespective of government R&D spending patterns, thereby increasing the relative share of industry's funding as compared with government's funding. Both of these considerations are reflected in funding patterns for industrial R&D performance alone (see Figure 3).

Figure 3: BERD by sources of funds (in percent)



Source: OECD (MSTI)

1.1.2 The rationale for public intervention

The willingness to increase the public spending on R&D and to widen the scope for public policies makes a discussion of the justification and legitimacy of public intervention useful. The general argument for public support of private R&D is well established: in most situations the market will fail to provide sufficient incentives to invest in R&D since firms face appropriability problems. The reason is that R&D has some characteristics of a public good, so that the private returns on innovation will be lower than its social return. This argument was well explicated by *Nelson* (1959) and *Arrow* (1962) even though their arguments were primarily aimed at the legitimacy of government support of basic research. The market failure argument has been further sophisticated by consideration of different types of market failures, which mark strong arguments for public support of private R&D. Hence, the scope for public policies has

been widened by encompassing the policy rationale for state support for public sector science and for financial support of industrial R&D.

Different types of spillovers in the generation of knowledge build one kind of market failure and call for public intervention. If firms cannot fully capitalize their discoveries due to the public good character of the research activities, they will invest in R&D less than would be socially optimal. That's why most studies have demonstrated that investment in R&D yield high returns to the investor and even higher returns to society (see *Klette et al.* 2000 for an overview). One review of econometric studies concluded that '... in spite of [many] difficulties, there has been a significant number of reasonably well done studies all pointing in the same direction: R&D spillovers are present, their magnitude may be quite large, and social rates of return remain significantly above private rates' (*Griliches* 1992). The types of spillovers encompass the appropriability of knowledge for instance through imitation, the benefits to use innovations not captured in the price or network spillovers (*Jaffe* 1996).

Another source of market failure is related to uncertainty and risk: in addition to the usual 'market uncertainty', whereby firms need to turn new products into commercial success, the technological uncertainty is to a large extent embedded in the nature of innovation. Due to the fact that every innovation process both generates and is influenced by uncertainty, this aspect of market failure is particularly damaging to the possibility of a Pareto efficient allocation of resources to invention and innovation. But this difficulty is deeply embedded in the nature of technological knowledge, the creation of which relies on the exploitation and generation of information asymmetries. 'In a quite fundamental sense, innovations and information asymmetries are one and the same phenomena. Indeed, such asymmetries can scarcely be termed market imperfections when they are necessary conditions for any technical change to occur in a market economy' (*Metcalf* 1995). However, risk-perceptions are mainly done by the investors (internally or externally). Too risky R&D projects may lead to under-investment in R&D compared to the socially optimum level. This in particular constitute constrains in the firms' access to external financing.

There is general agreement that these kinds of market failures will lead market mechanisms to fail to provide a socially optimal level of industrial R&D investments. Two categories of economic policies have been implemented in order to restore the socially desirable level of business R&D: the first category aims to increase its private return, the second category aims to decrease its private sunk costs. In order to increase the private return on innovation, many states have introduced intellectual property right protection granting the inventor a temporary monopoly over his or her discovery in order to avoid imitation. However, patents are not always an efficient incentive for firms to invest more into R&D. Moreover, patents also have social costs in terms of restricting the diffusion of technological improvements. Firms do consider patent protection neither as the only mean of appropriation nor as the most efficient. Secrecy or first move could be more efficient in securing innovation profits (*Griliches* 1990).

Within the second category – as a complement to the above measure – policy may seek to reduce the private sunk costs of R&D by influencing the incentives to invest in R&D. A subsidy modifies private incentives to engage in R&D by raising the expected returns of innovation and thus make more and riskier projects accepted by firms. It thus allows to overcome some of the constraints on external financing caused by risk and uncertainty perceptions. But it also involves an additional advantage when the associated knowledge is difficult to protect. Since subsidies are not property rights, they ensure that innovations will be spread through imitation activities of competitors. And the diffusion of new knowledge is always good from a social point of view. In our study we address only this measure – the issue of public subsidies to private R&D, thus research that is managed by the firms themselves.

Both kinds of measures coexist in most countries and have the rationale in common that pure markets will not be efficient in stimulating innovation due to the characteristics inherent to R&D. This justifies some kind of government intervention, although it is not trivial to decide which instrument to adopt, which firms should benefit and by how much and along which requirements subsidies should be allocated. This requires a detailed knowledge of the likely impact and effectiveness of different measures, including possible crowding out effects of public intervention.

2 Empirical evidence on additionality – the effects of public subsidies in Austria

The main problem which shall be addressed in this section is the additionality (or, more precisely, the *input additionality*) of R&D subsidies: do public contributions to private research boost total private R&D expenditures – and if so, do they boost them by an amount which is larger than the amount of taxpayers' money which was used in this way?

Besides input additionality, there are other concepts of "additionality" as well, notably *output* additionality (what is the effect of the subsidies research on a firm's turnover, profit, etc.) and *behavioural* additionality (in how far does the existence and availability of public subsidies alter firms' research decisions).

Moreover, input additionality will be defined primarily in a *contemporaneous* way: what is the immediate effect of a subsidy on R&D expenditures? For reasons to do with data availability, the longer term (how total R&D expenditures are influenced by subsidies in the long run) will not be dealt with.

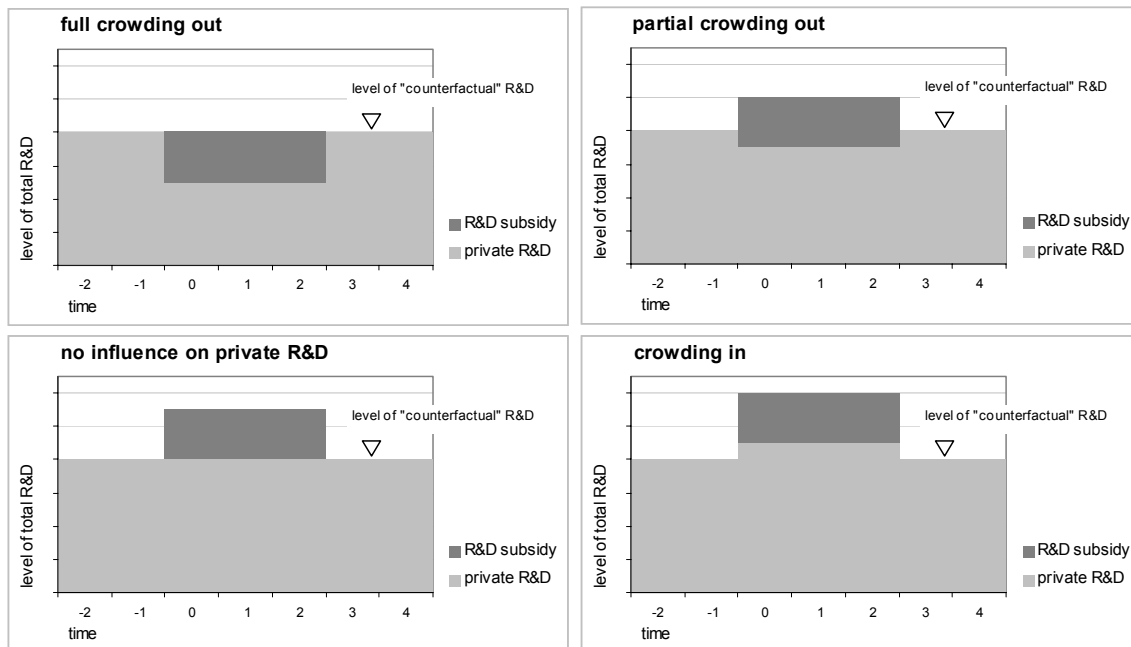
2.1 Some theoretical considerations

Given that the social return is higher than the private return of R&D the goal of a subsidy is quite clear: by granting a subsidy, the public investor hopes that additional research projects will take place compared to the ones that would have been done without the public support. This leads to the key issue of subsidy-based funding, i.e. the additionality, which ensures that government spending does not crowd out but rather stimulates additional private R&D investment. If public funding is directed towards projects that the firm would have been undertaken anyway, this would lead into a misallocation of resources. On the other hand, a complementary relationship between private and public funding would legitimize public intervention. The main difficulty in assuring the additionality arises from the asymmetric information between the subsidized firm and the government – the government does not know *ex ante* which kind of effect the subsidy will entail.

It is thus important to bear in mind that the level of R&D expenditures is the result of an internal decision process within in the firm; so are the reactions to R&D subsidies. Therefore, subsidies do not (or only partially) influence R&D directly, but rather indirectly: for the firm as a whole, the subsidy implies an outward shift of the budget constraint. The allocation of the additional funds within the firm, then, is subject to considerations involving "marginal benefit". Therefore, the effect of the subsidy on own R&D expenditures depends on many (internal and external) circumstances.

The following Figure 4 presents possible reactions of own R&D expenditures to a subsidy.

Figure 4: Effects of R&D Subsidies on Total R&D Expenditures ²⁾



Full crowding out occurs when firms perceive the subsidy as "windfall gains": in the face of a subsidy, firms do not change their R&D plans, but rather use the subsidy to reduce their own spending³⁾.

Partial crowding out occurs if firms raise their total R&D expenditures, but by less than the amount of the subsidy. This is probably the likeliest effect for firms which are not "liquidity constrained", meaning that their R&D plans are not kept down by (external) budget constraints (e.g., the inability to get bank credit). In the presence of liquidity constraints, a possible reaction to a subsidy might be an *unchanged level of own R&D expenditures*: the firm would like to do more R&D than it is able to afford because of banks' unwillingness to finance it. In this case, the firm would use the subsidy to extend total research by the full amount of the subsidy. If, additionally, the fact that the firm

²⁾ For simplicity, the level of the counterfactual R&D expenditures (i.e., those expenditures which would have been observed in the absence of any subsidy) is held constant over time

³⁾ In the context of the present analysis, "more than full" crowding out can be ruled out: it would imply that firms reduce their own R&D expenditures by more than the amount of the subsidy; total R&D spending (own expenditures + subsidy) would fall. This has been demonstrated in only a few very special cases, notably the SEMATECH program., which was set up in the 1980s to co-ordinate the research efforts of US-American semiconductor firms in order to counter the "Japanese menace". By reducing duplicate research, this program seems to have had a (significant) negative influence on total R&D expenditures on the part of participating firms (see *Irwin and Klenow*, 1995).

managed to secure a subsidy somehow results in a loosening of the liquidity constraint (if, say, banks perceive the grant as a positive signal, a "seal of quality", which leads to an extension of the credit line), a result might be a *crowding in*.

Reasons for *crowding in* might also be found in the internal decision process. When a firm allocates its total budget to its different departments (marketing, production, research,...), the shares each department is awarded is the result of an internal "struggle" between departments. If, again, the R&D grant acts as a stamp of approval, this might improve the research department's bargaining power, resulting in a larger budget share than would otherwise have been attainable.

2.1.1 Typical results: a quick literature survey

The econometric evidence of the substitutability or complementarity effects of public R&D funding is very inconclusive (following *David et al.* (2000), "substitutability" is taken to imply (even partial) crowding out; "complementarity" implies crowding in).

The empirical evidence on the effects of public subsidy is rather limited consisting of various 'additionality studies' with different methodological approaches (cf. *David et al.*, 2000). However, to be able to provide a common background only the firm level studies are mentioned. One can think of, among others, *Czarnitzki and Fier* (2001), *Meeusen and Janssens* (2001), *Lach* (2000), and *Irwin and Klenow* (1996), which extend the important work of *David et al.* (2000).

The comparison of the company-level studies indicates the difficulties of measuring leverage effects: roughly half of the studies indicate complementarity and substitution respectively. An interesting difference, though, can be observed between European and US-American studies.

Table 1 shows the results of the 18 econometric studies split into European and US studies. The difference is highly visible. The total of studies with substitution effects is 7 whereof 6 are studies analyzing US data and only one is a European study. The contrary is the case with complementarity of public R&D funding, where 5 out of 7 studies comprise data from European countries. Referring to *David et al.* (2000) this could be partly due to the fact that US studies very often measure the impact of government *contract* R&D on private R&D spending, whereas in Europe firms get government grants and loans instead of direct R&D contracts.

Table 1: Econometric results, geographically differentiated

study results	substitutability	complementarity	mixed results
USA	6	2	3
Europe	1	5	1
Total	7	7	4

It has to be noted, though, that the firm-level studies employ different methods and look at different sets of data at different periods of time, thus are not strictly comparable.

As to the size of the additionality effect⁴⁾, the studies in the survey exhibited a wide range of estimated values: this ranges from -6.5 (implying that an additional monetary unit of subsidies leads to a reduction of own R&D expenditures to the tune of 6.5 monetary units) to +8. Both extreme values look implausible: indeed, from the theoretical exposition above, a range of -1 (full crowding out) to, maybe, +2 or +3 seems more appropriate. Indeed, the -6.5 are the results of a study by *Toivanen and Niinen* (1998), in which they estimated additionality to be between -6.5 and +4.0, depending on firm type and specification⁵⁾. The only other study to find more than full crowding out, at -2, is the SEMATECH-study by *Irwin and Klenow* (1996). In this case, the large negative effect seems more plausible⁶⁾, as SEMATECH in essence constituted an R&D consortium: member firms pooled part of their R&D efforts. As this construction allowed for more efficient R&D in the sense of a prevention of some duplicate R&D, the "fuller than full" crowding out could be the result of this increased efficiency.

Closest to full crowding out, at a reduction in own R&D expenditures of 82 cents for every dollar of R&D subsidies, came the study of the Small Business Innovation Research program (SBIR) by *Wallsten* (2000). His conclusion was that SBIR subsidies mainly financed R&D projects which would anyway have been undertaken by the funded firms, because the funded projects were highly successful in commercial terms.

Most other studies in the survey exhibited modest-to-fair amounts of crowding in, of between +0.1 to some +2.5 of additional own R&D expenditures for every unit of subsidies. The extreme value of +7 was estimated in a study of 86 Italian firms by *Antonelli* (1989).

2.2 The data base

The data base was provided by the Austrian Industrial Research Promotion fund (FFF)⁷⁾. It comprises two parts: the first part contains information on the 3138 firms which applied (whether successfully or not) for FFF-funding during 1995 and September of 2003. The second part consists of information on the 8769 projects for which applications were filed during the aforementioned period.

⁴⁾ Numerical values for the additionality effects, in the sense that "1 unit of subsidies leads to x units of additional own R&D expenditures", could not be provided for all papers; *David et al.* (2000) do list additionality effects for most of the papers in their survey, but they included this effect as an *elasticity*, which is not very informative (the net effect is hard to estimate if the result is that "an additional 1 percent of subsidies results in an additional 0.07 percent of own R&D expenditures").

⁵⁾ Summing up, they conclude that "there is additionality for at least some firms".

⁶⁾ Although their study drew some heavy criticism for comparing large firms within the SEMATECH consortium with small firms outside the consortium, thereby implying problems with selection bias.

⁷⁾ The authors would like to thank Mag. Klaus Schnitzer and DI.Mag. Reinhard Zeilinger from the FFF for their cooperation.

The firm level data contain information which has to be provided when submitting an application. This includes general firm characteristics:

Turnover, cashflow, exports, number of employees, year of foundation, legal form, and location

Besides, R&D specific variables are collected:

R&D expenditures and R&D personnel

This information has to be provided for the three years prior to the application of a project. After the submission of the project, no further data are collected on the firm level.

On the project level, the data include:

classification of the project according to the NACE-definition of economic activity, planned duration of the project, planned project costs (disaggregated into personnel, equipment, other), and, if appropriate, a reference to the original project (for applications requesting continued funding for longer projects).

For successful applications, additional data are included:

time period for which funding is granted (for longer projects, funding is typically not granted for the whole period. After the approved funding period, an application for continued funding has to be submitted), the total amount of funding (nominal and present value), and the "funding mix".

The last point necessitates some explanation: typically, funding is granted to the tune of 50 percent of a project's costs⁸⁾ (60 percent in some cases). So, the *nominal* amount of funding is 50 percent (or 60 percent). Most projects, however, are financed by a mix of non-refundable contributions (from the FFF) and refundable loans (either a subsidised loan from the FFF or a business loan from a private bank, in which case the FFF's contribution consists in a debt guarantee or in allowances towards the loan's annuities, or both); together, these finance instruments amount to the aforementioned 50 percent of project costs. Therefore, the *present value* (PV) of the approved subsidies is smaller than their nominal amount. The share of the non-refundable part depends positively on the FFF's assessment of a project's riskiness and technological "new-ness" and negatively on economic potential. On average, the PV of funding represents 22 percent of total project costs (or about 47 percent of nominal subsidies). In all of the analyses, it is the reaction of R&D expenditures to this PV which will be of interest, not the reaction to the nominal amount.

From this description, two problems associated with this data base should be obvious. The first one has to do with the different periodicity of firm level and project level data:

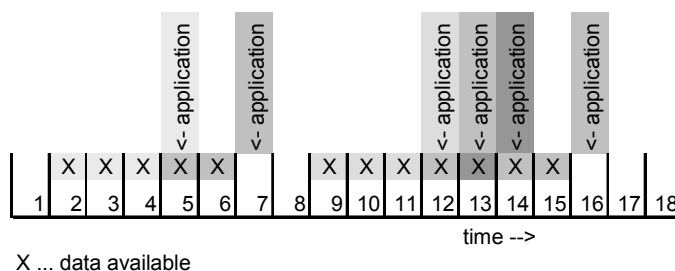
⁸⁾ These are "reviewed" costs: it is not necessarily the amount which the applicant asked for in his proposal. Rather, it is the costs which are "negotiated" between the applicant and the FFF.

whereas the former contains (discrete) annual data, the latter is based on "continuous time": a project can start and end at any day (or, rather, month) of the year. To solve this discrepancy, the subsidies' PV is proportionally distributed over the approved funding period: for example, if the funding period starts in November of 1997 and ends in June of 1999, thus spanning 20 months, 10 percent (i.e., 2/20) of total PV are counted as "funding in 1997", 60 percent (=12/20) are assigned to 1998, leaving 30 percent (=6/20) for 1999. This assumption of a linear deduction is certainly not "realistic" in the sense that firms use up their research funds in this linear fashion. However, given our ignorance about the "true" course of each project, this seemed to be the best solution (and it is certainly more realistic than simply allotting the whole amount to, e.g., the first project year).

The second problem is harder to solve: it has to do with the fact that from the way the firm level data are collected, firm level data and project level data cover completely separate periods: the firm level data span the three years *prior* to the project, leaving the period when the firm actually receives funding completely uncovered – not a very promising situation to start from when trying to estimate the effect of funding on the firms' total R&D expenditures.

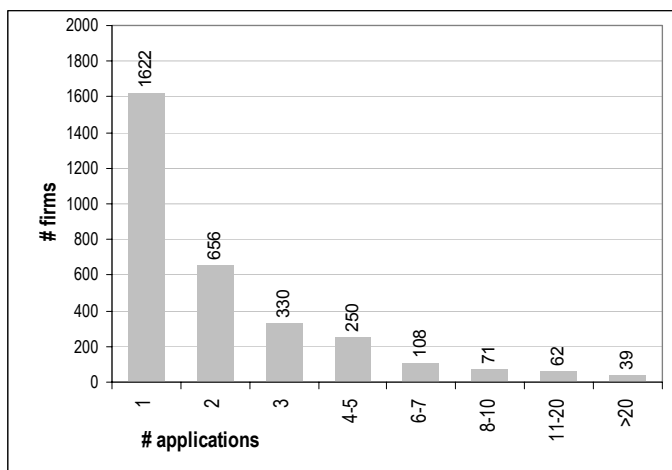
To solve this paradox, we have to rely on firms which have repeatedly applied for funding. For such firms, overlapping time series of both R&D and funding data might be constructed in the following way: say, a firm had applied for funding in 1997. This would imply that this firm had to report company statistics for the years 1994-1996. If this were the last application this particular firm had made, it would be the end of the story. If, on the other hand, this firm again approached the FFF in, say, the year 2000, the company statistics for the years 1997-1999, which the firm would have to report for the new application, could be used to obtain the information necessary for the evaluation of the project applied for in 1996; in an athletic analogy, this might be termed "relay method".

Figure 5: Constructing time series by the "Relay method"



Firms with repeated applications to the FFF are quite numerous: on average, each firm submitted almost 3 projects. The following Figure 6 shows a histogram of such "repeat offenders"

Figure 6: Number of firms by number of applications to the FFF, 1995-2003



Source: FFF; own calculations

Clearly, all 1600 firms (representing one half of all firms) which only applied once are "lost" for this analysis⁹). Unfortunately, firms with repeated applications also do not automatically qualify for inclusion in this analysis: their applications have to be "close enough" to provide for the required overlap of firm- and funding data (as an example: suppose in 1996 a firm submitted and started a project which lasted for one year. If this firm then came back with another application in 2002, this would be too late: firm level data would be available for 1993-1995 and then again from 1999-2001, whereas funding data would cover the years 1996 and 1997).

Applied to the FFF data base, this method produces a total of some 1100 firms, for which contemporaneous firm- and project data are available for at least one year (for different reasons, the sample of firms actually included in the analyses will be smaller still).

2.3 The model

Given the type of data as described in the previous section (time series data on quite a large number of individual firms), a logical framework for the estimation of the effect of FFF subsidies on firms' R&D expenditures is given by panel regressions. Under the assumption that (known and unknown) characteristics influence firms' R&D behaviour in a firm-specific but time-invariant way, incorporating firm fixed effects (i.e., a different constant for every cross-section unit) allow for the implicit modelling of these characteristics. This is quite convenient: although the data base contains information on some firm characteristics (turnover, export share, employees), most variables which

⁹) This is a pity because such "one-timers" conceivably represent a type of firm – those who only occasionally perform R&D – whose reaction to R&D subsidies is especially interesting. To facilitate future analyses, the FFF might contemplate to collect firm level data not only before the start of a project, but at the end as well.

might exert some influence are missing (most notably, firms' sector of activity). In the fixed-effects framework, such unobserved but time-invariant variables should be captured by the inclusion of firm-specific fixed effects.

Additionally, this model allows for every firm to act, in a way, as its own "control firm", in effect providing information on the firm's behaviour vis á vis different levels of support. This allows to overcome a major problem of the data base, the almost complete absence of firms which have some R&D activities but which did not get any subsidy.

Given the enormous range of firms in the database (from "owner-only" firms to companies with a couple of thousand employees), adequate correction for any potential (non-time invariant) size-effect must certainly be accounted for. It was found that a polynomial in annual turnover (averaged over two years) seems to provide this correction. Using the number of employees instead of annual turnover yielded roughly the same results; however, as turnover is the one variable which is available for every firm (data on employees were missing in about 5 percent of firm-years), turnover was used in the final specification¹⁰). Once size was "sufficiently" provided for, the inclusion of additional variables (employees, export share) seemed not to make much difference to the estimation results.

To allow for the disregard for the calendar year of the typical R&D project, lagged R&D expenditures are included. Lastly, year dummies were included to account for the panel's "unbalancedness": as data are not available for all firms and all years, each year's data comprise a slightly different sample of firms. As a tendency, the larger the firm, the more data-years are available.

The model, then, can be written as

$$R \& D_{i,t} = \lambda R \& D_{i,t-1} + \alpha subsidies_{i,t} + \sum_{k=1}^4 \beta_k ((turnover_{i,t} + turnover_{i,t-1}) / 2)^k + \sum_{t=1998}^{2002} D_t + \gamma_i + \varepsilon_{i,t}$$

The model was estimated for the years 1997-2002. Although project data were available since 1995, the years 1995 and 1996 were not used in the estimation process. The reason for this is the fact that the typical period for which FFF funding is provided is about 18 months. Therefore it cannot be ruled out (in fact, it is more than likely) that pre-1995 funding persists in the following years. To prevent this unknown source of funding from "contaminating" the estimates, the first two years were dropped.

¹⁰) Cashflow, which also would have been available, was disregarded. The reason for this is that quite a few definitions of cashflow are in use; it was not clear whether all firms used the same one. Additionally, as cashflow is an accounting concept similar to profits, R&D expenditures, being a cost component, enter the calculation of cashflow, thus potentially introducing problems with "simultaneity".

The final sample comprised 495 firms. These were selected according to the following criteria:

- a minimum of 4 observations in 1997-2002, to preserve the "time-series" flavour of the panel regression
- no "problematic" values of their R&D expenditures, defined as an amount of R&D expenditure which is less than the contemporaneous amount of (approved) project costs as recorded in the data base.
- no "problematic" values of annual turnover. A few firms reported sales which amount to more than a million euro per employee. Although such values are not strictly impossible, they were interpreted as indicators of possibly erroneous data (the cut-off was actually set at 500 000 euro/employee).
- included were only firms which consistently reported positive R&D expenditures. The reason behind this restriction is the idea that habitual R&D performers react differently to R&D subsidies than intermittent performers: as an extreme case, suppose a firm had performed only a single R&D project which was supported by the FFF. This firm, then, should exhibit R&D expenditures which are about twice the nominal amount of the granted sum (typically, 50 percent of project costs are covered by FFF subsidies) and about 4-5 times the amount of the subsidy's present value (as the typical funding mix consists of grants and loans, the present value, at about 22 percent on average, is less than the nominal amount). For this reason, the effect of FFF funding on non-habitual R&D performers is suspected to be larger than for firms which perform R&D on a more regular basis¹¹).

Altogether, 495 firms fulfilled the complete set of criteria, 35 of which did not receive any FFF funding during the observation period (despite their being regular R&D performers).

Using this set of 495 firms, the model was estimated using GLS with cross-section weighting. The results are presented in Table 2 below.

According to the estimation results, one additional Euro of funding (or, rather, of its present value) leads to an increase in (total) R&D expenditures of 1.40 Euros – or, put differently, an additional 40 cents of private R&D expenditures for each Euro of funding. FFF funding and private R&D, therefore, seem to be complementary, though the "leverage effect", at 40 percent, is not particularly large. Moreover, the complementarity can only be established for the *present value* of FFF funding: for the *nominal* amount of FFF subsidies, a substitution effect has to be admitted (the present value being about half of the nominal subsidy, the coefficient of the nominal funding would be calculated at about 0.7; a re-estimation of the model using nominal funding instead of the present value confirms this value).

¹¹) Estimation results seem to vindicate this assumption: for the 33 firms which were identified as "intermittent R&D performers" (defined as firms which report at least 2 years of zero R&D), the level of additionality is indeed estimated to be considerably higher; cf. below.

Table 2: Results of the fixed-effects panel regression

dependent variable: R&D expenditure
 estimation period: 1997-2002
 estimation method: GLS (cross-section weights)

	<i>coefficient</i>	<i>s.e.</i>	<i>prob-value</i>
R&D expenditure(-1)	0.701	0.02	0.00
FFF funding (present value)	1.400	0.07	0.00
(turnover+turnover(-1))	0.008	0.00	0.00
(turnover+turnover(-1)) ²	-2.80E-08	7.40E-09	0.00
(turnover+turnover(-1)) ³	5.40E-14	1.28E-14	0.00
(turnover+turnover(-1)) ⁴	-1.40E-20	3.98E-21	0.00
Dummy 1998	-18.10	3.53	0.00
Dummy 1999	-13.34	3.83	0.00
Dummy 2000	-27.91	4.19	0.00
Dummy 2001	-85.36	8.38	0.00
Dummy 2002	89.92	15.04	0.00
# cross-section units	495		
# observations	2194		

Source: FFF data base; own calculations

All coefficients are highly significant. With an estimated standard error of 0.07, the 95 percent-range of the funding coefficient is about 1.26-1.54, comfortably above a value of 1.0 which would constitute the boundary between "substitutability" and "complementarity": if the coefficient were less than 1.0, it would have to be concluded that firms substitute R&D subsidies for own expenditures (at least partially).

2.3.1 Standard errors revisited: a bootstrap approach

This happy result, that the funding is complementary "almost certainly", warrants some cautionary remarks: it is estimated under the usual assumption that the residuals are normally distributed. Conceivably, this might be implausible: the estimation is performed on the *level* of R&D expenditures as well as turnover; even if the size effect is properly taken care of, the residuals certainly remain affected by the level of a firm's typical R&D expenditures. Additionally, they are probably distributed as log-normal rather than normal (if they are normally distributed at all). To assess the extent to which the standard errors' estimates might be biased, a bootstrap exercise was performed. In this, the original sample of 495 firms was resampled 1000 times. For each bootstrapped sample, the model was re-estimated. The distribution of the 1000 coefficients of FFF funding were then statistically analysed.

The following Table 3 presents the summary statistics of this bootstrap.

Table 3: Results of the bootstrapping: descriptive statistics and Kernel density approximation

	bootstrapped funding coefficient (n=1000)
Mean	1.497
Median	1.422
Std. Dev.	0.594
Maximum	4.151
Minimum	-0.122
2.5% limit	0.534
97.5% limit	2.771
Jarque-Bera	95.153

The results are clear: the average of the bootstrapped coefficients, at about 1.50, is somewhat higher than the point estimate for the whole sample of 495 firms. The real difference, however, can be found for the estimated range of the funding coefficient: whereas our original results indicated a narrow range of [1.26, 1.54] for the 95 percent interval, the bootstrap yields, also at the 95 percent level, a range of [0.53, 2.77] – in other words, more than 10 times the range of the original estimate. Accordingly, the previous conclusion that complementarity of FFF funding is "almost certain" (provided that our model is valid, of course), has to be downgraded to "most probably" (about 80 percent of the bootstrapped coefficients are larger than 1).

In the next two sections, a closer look will be taken at two specific questions. The one is if additionality is a matter of firm size; the other, whether firms which do not perform R&D on a continuous basis exhibit different reactions to FFF funding.

2.3.2 Additionality – a function of firm size?

For the whole sample of 495 firms, a leverage of about 40 percent was estimated. In this section, the model will be re-estimated for samples of firms of different size. Firms were assigned to 4 different categories according to the average reported number of employees: less than 10, 10-50, 50-250, more than 250. The following Table 4 gives the results from the 4 panel regressions.

All firm sizes exhibit complementarity, though to a differing degree. Interestingly, it is the smallest and the largest firms which exhibit the highest leverage, medium-sized firms show only small additionality. At first sight, this is puzzling: one would probably suspect a homogeneously falling reaction of additionality with respect to firm size.

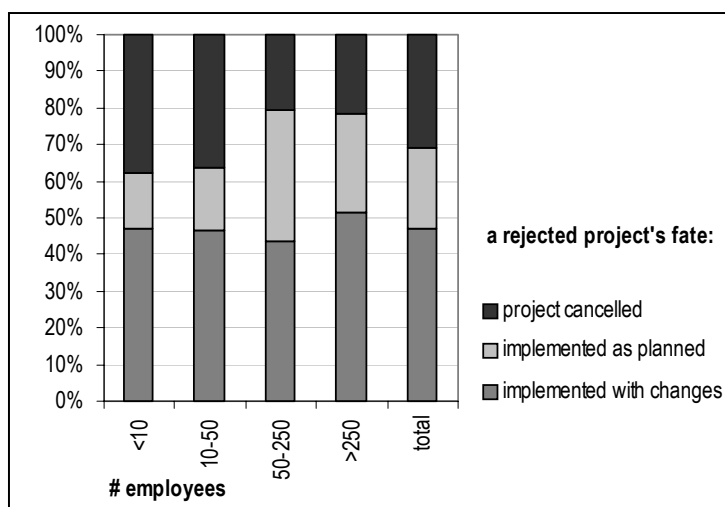
Table 4: Model results disaggregated by firm size

dependent variable: R&D expenditure
 estimation period: 1997-2002
 estimation method: GLS (cross-section weights)

	< 10 employees		10-50 employees		50-250 employees		>250 employees	
	coefficient	s.e.	coefficient	s.e.	coefficient	s.e.	coefficient	s.e.
R&D expenditure(-1)	0.088	0.04	0.413	0.03	0.458	0.04	0.771	0.03
FFF funding (present value)	1.621	0.15	1.293	0.09	1.048	0.17	1.955	0.26
(turnover+turnover(-1))	0.153	0.06	0.046	0.02	0.022	0.02	0.003	0.00
(turnover+turnover(-1)) ²	-1.9E-05	1.35E-04	5.9E-06	5.91E-06	2.3E-06	7.77E-07	-1.6E-08	1.11E-08
(turnover+turnover(-1)) ³	-5.4E-08	9.72E-08	-9.9E-10	6.62E-10	-5.5E-11	1.26E-11	3.8E-14	1.59E-14
(turnover+turnover(-1)) ⁴	1.4E-11	1.78E-11	3.4E-14	2.38E-14	2.6E-16	6.17E-17	-9.9E-21	4.73E-21
Dummy 1998	-1.454	4.42	8.818	4.80	7.137	12.85	-42.569	5.94
Dummy 1999	3.924	4.89	3.029	5.12	-18.311	21.66	-42.933	22.80
Dummy 2000	10.019	5.02	9.139	5.33	-55.753	24.44	-5.919	26.30
Dummy 2001	15.679	5.41	17.954	6.66	-62.808	29.33	-202.459	54.47
Dummy 2002	11.650	5.90	22.043	9.20	-98.867	27.53	120.214	85.19
# cross-section units	66		146		143		136	
# observations	259		607		651		746	

bold numbers indicate significance at the 10 percent level

Figure 7: Implementation/non-implementation if application was rejected: analysis by firm-size



Source: FFF- Survey

Candidates for the solutions to this puzzle can come from various corners. The first – and easiest – is certainly that this result is something of a statistical artefact, probably due to an inadequate model¹²). Of course, this cannot be ruled out. On the other hand, this

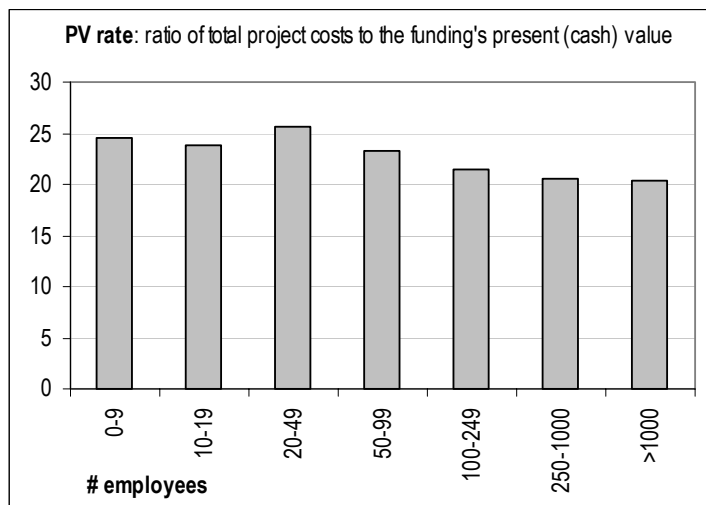
¹²) Although different model specifications exhibited similar patterns of additionality with respect to firm size.

U-shaped function reflects results from a survey¹³⁾ which was conducted specifically for the purpose of evaluating the "behavioural effects" of FFF funding. In this survey, firms were asked – among other things – whether rejected projects were conducted despite this negative decision, if they were conducted in a modified way, or not at all. Interestingly, the answers, presented in Figure 7, show a similar pattern when disaggregated into size classes.

According to the survey, medium-sized firms, more often than large and much more often than smaller firms, report that they implemented a project "without changes" even when confronted with a rejection. They also cancelled projects less often (although only slightly less often than large firms)¹⁴⁾. Although this result does not "explain away" the whole difference in additionality between firms of different sizes, it seems to hint at similar tendencies.

A third explanation, then, is certainly the fact that large firms face a lower PV rate than smaller firms: the ratio of total project costs to the funding's present value is some 15 percent lower than that of medium-sized firms (which enjoy the highest PV rates). In fact, the PV rate, disaggregated by firm size resembles an inverted U-shape (as such, it is the mirror-image of the additionality by size class):

Figure 8: PV rates by size class



Source: FFF; own calculation

¹³⁾ This survey was conducted within the evaluation of the FFF. For further information see *Schibany et al.* 2004

¹⁴⁾ From the cancellation rate as reported in the survey and a couple of bold assumptions, a (very) rough value for funding additionality can be derived: in total, about 30 percent of rejected projects were aborted. Assume that 100 projects were submitted. If all had been rejected, only 70 of them would have been conducted (either unchanged or modified), 30 would have been dropped altogether. Suppose further, each project would carry costs of 100 euros. Then, with the 30 dropped projects, 3000 euros of R&D expenditures would not have been spent. The funding of all 100 projects, at an average PV rate of 22 percent, would have cost the FFF 2200 euros. This translates into an "R&D leverage" of $3000/2200 = 1.36$, or about 36 cent of additional private R&D for every euro of FFF subsidies. But, of course, this is only a naive assessment.

A lower PV rate, then, implies higher additionality for each project: as the FFF's share in total project costs becomes smaller, the "funding leverage" becomes higher: an PV rate of 25 percent implies a leverage of 400 percent; an PV rate of 20 percent, one of 500 percent. Together with the different reaction to a rejection, this might provide a partial solution to the "leverage puzzle".

2.3.3 Additionality in firms with sporadic R&D activities

In the estimation of the model as presented above, only such firms were included which performed R&D on a regular basis. A firm was categorized as "regularly R&D performing", if in every year for which data on turnover were provided, a positive amount for R&D expenditures was reported. This restriction was justified on the ground that firms which regularly perform R&D might conceivably exhibit a weaker reaction to funding than firms which perform R&D only intermittently. In this section, this hypothesis shall now be dealt with.

For this, firms with intermittent R&D were identified as firms which reported zero R&D for at least one year for which data on turnover is available (and which fulfilled the other requirements for "sensible data" as stated at the beginning of chapter 2.3). Additionally, firms with at least 2 and 3 years of zero R&D were identified. The number of such firms is small: only 61, 33, and 18 could be identified, respectively.

Table 5: Additionality of firms with intermittent R&D performance

	at least 1 year of 0 R&D		at least 2 years of 0 R&D		at least 3 years of 0 R&D	
	coefficient	s.e.	coefficient	s.e.	coefficient	s.e.
R&D expenditure(-1)	0.236	0.08	-0.232	0.13	0.110	0.14
FFF funding (present value)	1.560	0.29	6.603	1.06	3.571	0.67
(turnover+turnover(-1))	0.039	0.03	0.509	0.10	0.161	0.07
(turnover+turnover(-1)) ²	-2.6E-07	2.14E-06	-2.3E-05	5.00E-06	-8.4E-06	5.57E-06
(turnover+turnover(-1)) ³	-1.6E-11	5.72E-11	4.3E-10	9.99E-11	2.7E-10	2.10E-10
(turnover+turnover(-1)) ⁴	2.0E-16	4.60E-16	-2.8E-15	6.94E-16	-3.0E-15	2.49E-15
Dummy 1998	28.976	24.09	8.785	19.37	-16.723	63.72
Dummy 1999	83.721	22.90	47.019	29.78	-31.301	63.40
Dummy 2000	89.017	22.95	30.593	33.83	30.103	64.64
Dummy 2001	115.574	24.54	-28.556	48.75	-34.116	67.04
Dummy 2002	181.217	42.48	51.380	87.71	49.112	99.49
# cross-section units	61		33		18	
# observations	226		119		65	

From the results it could be inferred that firms which do not perform R&D on a regular basis indeed exhibit a more pronounced response to R&D subsidies: although firms with at least 1 R&D-free year show only slightly higher leverage than regular R&D

performers (1.56 vs. 1.40), firms with 2 or 3 years of zero R&D are credited with markedly higher estimates. Nevertheless, it has to be borne in mind that the panels on which these results were obtained are quite small; the estimated standard errors of the funding coefficient are quite large, implying a wide confidence interval (which furthermore, as argued in chapter 2.3.1, is likely to be estimated as much too narrow).

2.4 Concluding remarks

What, now, can be said in answering the question whether FFF funding acts as a compliment or a substitute to privately financed R&D? The evidence can be interpreted as leaning towards complementarity: the results of the panel regression model certainly point in this direction, even if a bootstrap exercise adds some qualifications to this result. As for the leverage of FFF funding's numerical value, the analysis seems to place it at about 40 percent; 1 additional euro of funding (or, to be more precise, of its present value) induces firms to contribute an additional 40 cents of their own money. Both very small and large firms seem to exhibit higher leverage, small and medium-sized firms smaller leverage. Additionally, the leverage estimates for firms which perform R&D only occasionally are higher than for regular R&D performers.

In the whole analysis, there are some sources of shakiness: first of all, funding from sources other than the FFF are unknown. Although the FFF is by far the most important source of public subsidies to private R&D in Austria, it is certainly not the only one. The direction of the bias thus introduced is not completely clear: if funding by the FFF and funding by other sources are positively contemporaneously correlated, the analysis is likely to overstate the complementary effect; conversely, a negative correlation would dampen the estimated effect¹⁵). Whatever the direction, this unknown influence is unlikely to completely alter the results of the analysis (after all, the FFF accounts for about 80 percent of all public R&D subsidies to private R&D). Also, the (somewhat arbitrary) linear distribution of the subsidies over the respective funding periods certainly introduces some (unavoidable) "fuzziness". Longer time series would be of special importance to alleviate this problem by allowing some "averaging out" of mis-distribution introduced via the linear method.

The next is the choice of firms to enter the analysis. As it is, the standards for data quality are set rather high (at least 4 years of "sensible" data, etc.). As the bootstrapping exercise showed, even a varying set of firms which fulfil the same standard of data quality leads to a rather wide range of estimates. It shall not be concealed that the choice of functional form is of crucial importance as well; the results as presented in this paper are based on only one of quite a few specifications which were tested in the course of this work (albeit the one which was deemed to be the "best specification", of course).

¹⁵) If funding by other sources coincides with FFF funding, the subsidies from the other sources would be part of total R&D expenditures, thus raising the estimated effect of FFF funding on total R&D expenditures. Conversely, if funding by the FFF and other sources took place in different years, the other sources would raise total R&D spending in years without FFF funding, thereby dampening the estimated "jump" in R&D expenditures resulting from FFF funding.

Using the lagged endogenous variable, furthermore, might introduce Nickell-Bias, resulting in additionality estimates which are probably too conservative. Also, the dynamic formulation of the model conceivably renders the results as the "lower limit" of additionality.

But whatever the "right" specification actually might turn out to be, any econometric analysis is bound to be confronted with a vast amount of "noise" hidden in this data base (which is not to say that the data are "inaccurate"; rather, too much of what actually gets on inside any firm and which influences the amount of realised R&D remains necessarily unknown).

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