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ADDITIONALITY OF FFG FUNDING

FINAL REPORT

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Abstract:

This paper re-visits the question of input additionality with respect to R&D subsidies granted by the Austrian Forschungsförderungsgesellschaft FFG (formerly FFF). FFG is the agency in charge of the major share in public subsidies to firm-level R&D, distributing some € 145 Mio (present value, 2005) under the title "Basisprogramme". The main question is the reaction of firms to these subsidies with respect to their own outlays on R&D: is FFG funding a complement to or a substitute for privately funded R&D?

The analysis is based on firm-level data for the period 1995-2006, provided by FFG. Using panel estimation methods, the paper concludes that input additionality is significant, amounting to about 30 cents for each Euro of subsidies' present value in the short run and about 85 cents in the long run, pointing strongly in the direction of complementarity (this implies that in the long run, 1 € of subsidies leads to an expansion of total R&D of almost 2 €). Although sizable – and comparing quite well with results from similar international studies - this is less than could "naively" be expected from FFG's terms of business. Also, as the margin of error for the estimates is quite large (depending to a large extent on the specific group of firms used in the estimation), precise numbers for additionality should be treated with some caution. t

Keywords: R&D subsidies, technology policy evaluation, additionality, panel estimation.

JEL Classification: O31, L52, H32

ABSTRACT

This paper re-visits the question of input additionality with respect to R&D subsidies granted by the Austrian Forschungsförderungsgesellschaft FFG (formerly FFF). FFG is the agency in charge of the major share in public subsidies to firm-level R&D, distributing some € 145 Mio (present value, 2005) under the title "Basisprogramme". The main question is the reaction of firms to these subsidies with respect to their own outlays on R&D: is FFG funding a complement to or a substitute for privately funded R&D?

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KURZFASSUNG

Vorliegende Arbeit befasst sich mit der Inputadditionalität von Forschungsförderung durch die Forschungsförderungsgesellschaft FFG (früher FFF). Mit etwa 145 Mio € an Förderbarwert, die von der FFG unter dem Titel Basisprogramme im Jahr 2005 vergeben worden sind, vergibt die FFG einen Großteil der öffentlichen Fördergelder für Forschung der gewerblichen Wirtschaft. Die Frage, wie sich diese Förderungen auf die firmeneigenen Ausgaben für F&E auswirken, ist Gegenstand der vorliegenden Studie: ersetzen Fördergelder (eventuell teilweise) eigene Mittel (Substitution), oder bewirken sie im Gegenteil sogar eine Ausweitung der firmeneigenen Ausgaben (Additionalität)?

Die Datenbasis enthält Struktur- und Förderdaten auf Firmenebene und umfasst die Periode 1995-2006; sie wurde von der FFG zur Verfügung gestellt. Eine Panel-Schätzung ergibt eine signifikant additive Förderwirkung: jeder Euro an Förderbarwert bringt kurzfristig eine Ausweitung der firmeneigenen Forschungsausgaben um etwa 30 Cent, langfristig liegt der Effekt bei etwa 85 Cent (d.h., dass die gesamten F&E-Ausgaben um fast 2 € pro 1 € Förderbarwert steigen). Der Fördereffekt ist also durchaus beträchtlich (auch im Vergleich zu den Resultaten vergleichbarer internationaler Studien), wenn auch geringer als der Effekt, der sich bei einer „naiven" Betrachtung der Förderbedingungen ergibt. Eine Sensibilitätsanalyse zeigt darüber hinaus, dass die Resultate relativ stark von der spezifischen Auswahl der in der Analyse verwendeten Firmen abhängen; die genauen numerischen Resultate sind daher mit einer gewissen Vorsicht zu interpretieren.

Keywords: R&D subsidies, technology policy evaluation, additionality, panel estimation.

JEL Classification: O31, L52, H32

1 Introduction

During the years 2003 and 2004 an international evaluation of the two most important Austrian research funds, the FFF [1] (for industry) and FFW [2] (for academia) was conducted. Part of this evaluation exercise was an impact analysis of the FFF, which consisted of three additionality sections which dealt with input, output, and behavioural additionality, respectively (see Schibany et al., 2004). Three years on, one of these sections is revisited with the present paper: the topic of input additionality. The question which will be asked – and which was asked then – is: what is the effect of FFF (now part of the FFG [3]) funding on the funded firms' private R&D expenditures? Input additionality thus investigates whether publicly funded R&D is complementary and thus 'additional' to privately funded R&D spending – or if, on the other hand, public R&D subsidies crowd out private R&D expenditures.

The present paper will expand the study on input additionality along the temporal dimension (via the inclusion of 4 additional years of observation) as well as with respect to the estimation methodology.

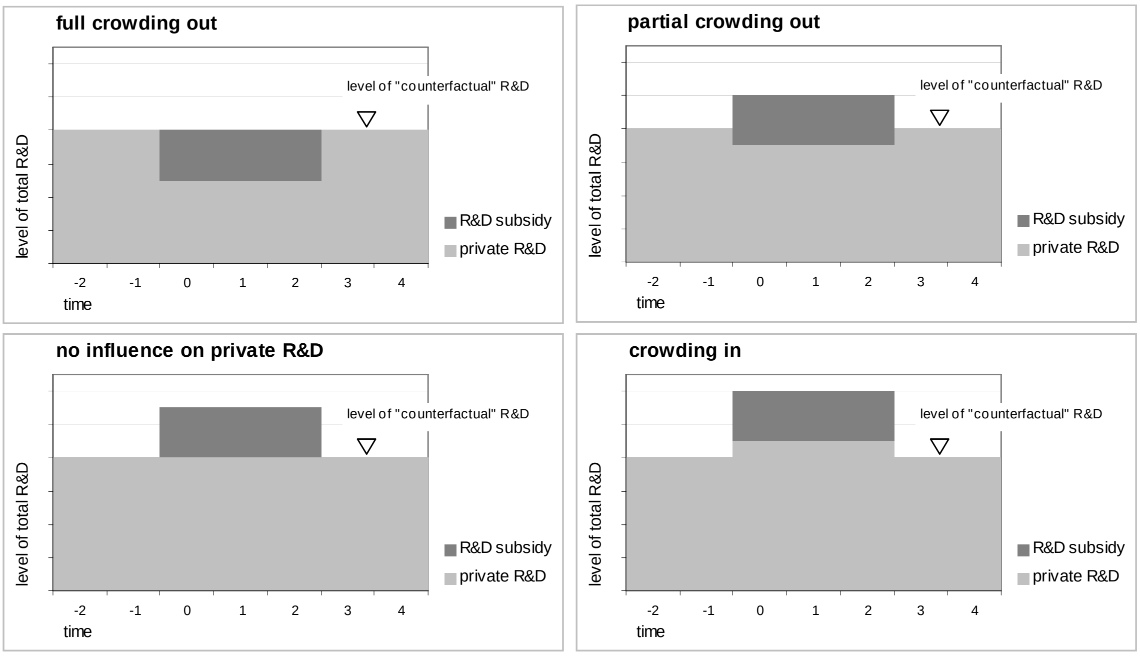
1.1. THEORETICAL CONSIDERATIONS

It is 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 1 presents possible reactions of own R&D expenditures to a subsidy.

[1] Forschungsförderungsfonds
[2] Fonds zur Förderung der wissenschaftlichen Forschung; www.fwf.ac.at
[3] Forschungsförderungsgesellschaft; www.ffg.at

Figure 1: Effects of R&D Subsidies on Total R&D Expenditures [4]



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 spending[5].

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 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.

1.1.1 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).

[4] 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

[5] 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 programme seems to have had a (significant) negative influence on total R&D expenditures on the part of participating firms (see Irwin and Klenow, 1995).

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 effect[6], 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 specification[7]. 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 plausible[8], 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.

[6] 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 % of subsidies results in an additional 0.07 % of own R&D expenditures")

[7] Summing up, they conclude that "there is additionality for at least some firms"

[8] 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.

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).

1.2. THE DATA BASE

The data base consists of two parts: one contains project-level data from 1995, the other contains firm-level data (starting 1995 as well). The latest entries for both are from November 2006 [9].

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 % of a project's costs[10] (60 % in some cases). So, the *nominal* amount of funding is 50 (or 60) %. Most projects, however, are financed by a mix of non-refundable contributions (from the FFG) and refundable loans (either a subsidised loan from the FFG or a business loan from a private bank, in which case the FFG'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 % 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 FFG's assessment of a project's riskiness and technological "new-ness" and negatively on economic potential. On average, the PV of funding represents 22 % of total project costs (or about 47 % 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.

1.3. OVERVIEW OF PROJECT-LEVEL DATA

The FFG does not constitute a "single" fund; rather, it is divided in quite a few different funds (which also differ with respect to their funding policies). From 2002, the situation got even more complex, as the formerly independent FFF (*Forschungsförderungsfonds*), which constitutes the biggest fund (which, nevertheless, managed not only its "own" fund, but also other funds, most importantly one financed by

[9] The author would like to thank FFG in general and Reinhard Zeilinger in particular for providing access to the data base.

[10] 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.

the Austrian National Bank, OeNB) was merged with other funding agencies; as a result, the data base contains 53 different funds:

Fund	subsidy (non-refundable) [1000 €]	PV [1000 €]	share of subsidy	# applications	# grants	success rate	average PV per grant [1000 €]
FFG	625,719	851,818	73%	11,821	8,275	70%	103
OeNB	167,332	194,861	86%	614	591	96%	330
NATS	116,743	140,195	83%	462	448	97%	313
K-ind	121,537	121,537	100%	48	42	88%	2,894
Kplus-EM	112,214	112,214	100%	29	29	100%	3,869
ITF	50,178	50,251	100%	624	455	73%	110
Head	36,686	37,151	99%	42	39	93%	953
Kplus-TH	36,745	36,745	100%	12	12	100%	3,062
FIT-IT	30,429	30,429	100%	224	107	48%	284
GEN-AU	26,903	26,903	100%	21	21	100%	1,281
A3	18,298	18,298	100%	130	69	53%	265
Brücke N	18,236	18,236	100%	230	112	49%	163
HdZ	15,780	15,780	100%	305	128	42%	123
FdZ	13,577	13,577	100%	325	121	37%	112
AplusB-EM	13,505	13,505	100%	6	6	100%	2,251
Aero	13,485	13,485	100%	54	41	76%	329
ASAP	11,984	11,984	100%	42	42	100%	285
EdZ	10,932	10,932	100%	251	85	34%	129
FHplus-EM	10,612	10,612	100%	21	21	100%	505
WAFÖ	9,580	9,580	100%	85	84	99%	114
Prokis	8,885	8,885	100%	22	18	82%	494
ISB	8,380	8,380	100%	100	41	41%	204
FHplus-TH	7,725	7,725	100%	24	24	100%	322
KOM	5,789	6,795	85%	98	96	98%	71
protec-TH	6,306	6,306	100%	49	37	76%	170
FH	6,084	6,084	100%	62	31	50%	196
PUST-TH	5,877	5,877	100%	19	19	100%	309
I2	5,752	5,752	100%	32	32	100%	180
NANO	5,490	5,490	100%	89	41	46%	134
AplusB-TH	5,001	5,001	100%	4	4	100%	1,250
Brücke B	4,995	4,995	100%	54	36	67%	139
REGplus-EM	4,018	4,018	100%	24	24	100%	167
Artist	3,389	3,391	100%	25	25	100%	136
IMP	2,990	2,990	100%	39	39	100%	77
WR-Koop	2,595	2,595	100%	2	2	100%	1,297
SELP-EM	2,400	2,400	100%	3	3	100%	800
A3_LP	2,153	2,153	100%	5	5	100%	431
CIR-CE-TH	2,048	2,048	100%	14	14	100%	146
ÖWP2005-TH	1,725	1,725	100%	4	4	100%	431
REGplus-TH	1,690	1,690	100%	11	11	100%	154
Head N	1,450	1,468	99%	3	3	100%	489
HdZ-BM	1,082	1,082	100%	38	13	34%	83
Biomed	983	983	100%	25	6	24%	164
I2-LP	882	882	100%	2	2	100%	441
FEMtech-TH	842	842	100%	28	28	100%	30
ISB-BM	475	475	100%	26	6	23%	79
eCont	128	128	100%	27	23	85%	6
ÖWP2005-EM	80	80	100%	1	1	100%	80
BWK	65	73	90%	2	2	100%	36
EdZ-NW	70	70	100%	1	1	100%	70
**Demo	60	60	100%	1	1	100%	60
HdZ-NW	35	35	100%	1	1	100%	35
WR2000	28	28	100%	1	1	100%	28
Total	1,559,948	1,838,599	85%	16,182	11,322	70%	162

Source: FFG; own calculations

In total, subsidies amounting to a present value of 1.8 Bio € were granted in the period 1995-November 2006. About 84 % was made up of non-refundable grants (the rest are subsidised loans, allowances towards commercial loan's annuities or debt guarantees). Average funding per project had a present value of 160 k€; 70 % of applications were accepted for funding.

The most important fund is the FFG (formerly FFF) fund (with 850 Mio €, it accounted for almost half of all funding), followed by OeNB and NATS (both are financed by the Austrian National Bank, with co-financing of the NATS by the ERP fund; the NATS replaced the OeNB fund in 2002), which together amount to a PV of 330 Mio € (18 %).

Typically (at least for the FFG, OeNB and NATS funds), funding is a mix of refundable and non-refundable subsidies: around 20 % of a project's (accepted) costs are paid as non-refundable grants (a bit more for smaller firms, somewhat less for larger). What remains of half a project's costs (the maximum amount for which subsidies may be granted) constitutes refundable support in the form of loans or credit subsidies. Together, the present value of non-refundable and refundable support amounts to about a quarter of average project costs.

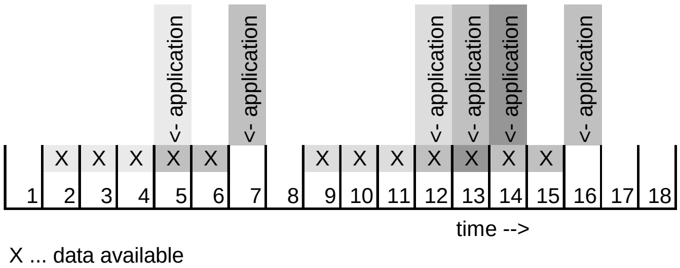
1.4. MATCHING OF FIRM- AND PROJECT-LEVEL DATA

From the above 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: 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 % (i.e., 2/20) of total PV are counted as "funding in 1997", 60 % (=12/20) are assigned to 1998, leaving 30 % (=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.

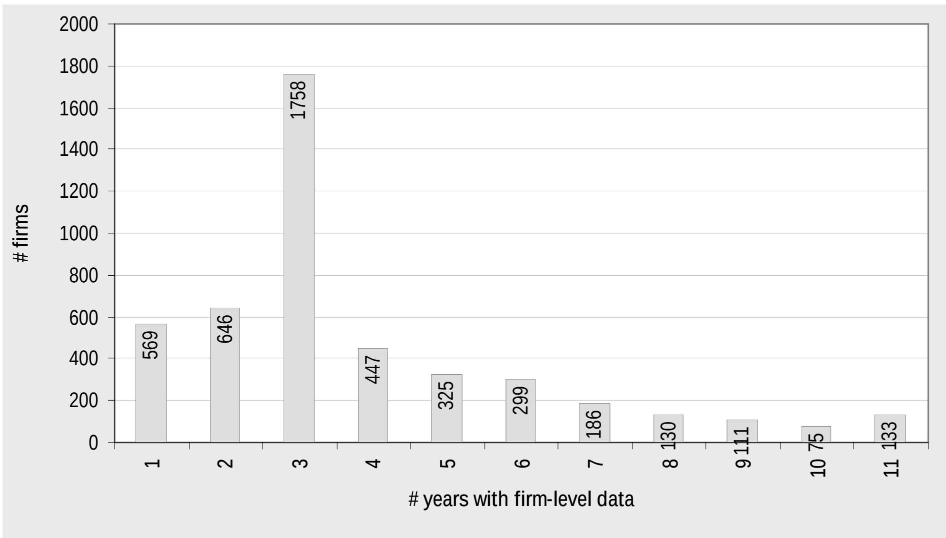
To solve this paradox, we have to rely on firms which have repeatedly applied for funding. For such firms, overlapping time series of both R&D and funding data might be constructed in the following way: say, a firm had applied for funding in 1997. This would imply that this firm had to report company 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 2: 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. Accordingly, “sensible” time series of firm-level data can be constructed for quite a few firms, as the following Figure 3 shows:

Figure 3: Number of firms by availability of firm-level data, 1995-2005



Source: FFG; own calculations

All in all, 4679 firms (or, rather, organisations) are covered in the data base. Although with 3 (or fewer) observations, a majority (2973) is clearly inadequate (as for these, there is no way of obtaining overlapping firm- and project-level data), there are 934 organisations with 6 or more firm-level observations (208 have 10 or 11)[11]. From these, the sample for the econometric analysis will come from.

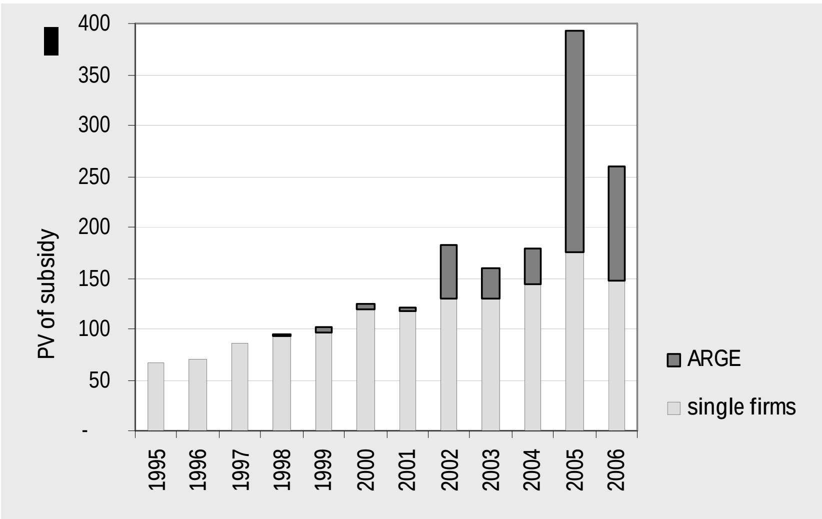
An additional restriction on the number of available firms is posed by the fact that FFG funding is also awarded to academic institutions (e.g., when they are part of a consortium). As the focus of this study is on the firm, academic institutes were (manually) removed from the data base. Along with these, pure research organisations (extra-university research organisations like ARCS, JR, but also private organisations like AVL List) were eliminated, due to their different motivation for R&D (as an “entrepreneurial end in itself” rather than a “means to an end”) . All in all, 602 organisations were

[11] 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).

identified as belonging to this group, leaving 4077 “genuine” firms in the data base’s population, on which the following chapters will be based.

Still another problem has to do with consortia (*ARGE-Arbeitsgemeinschaften*): up until 2001, most (but not all) funds were handed over to single firms; for these funds, the attribution of funds to firms is straightforward. Especially since 2002, however, increasing amounts of funs were awarded to consortia, i.e. ad-hoc groups of firms (and probably academic institutions). In order to solve the present study’s task, to estimate the effect of FFG funding on private R&D expenditures, the funds awarded to some consortium have to be distributed to the firms which participate in it. For some consortia, the distribution of the funds among the constituent firms was contained in the data base. If this was not the case, the total amount was evenly distributed among the constituent firms (if a consortium consisted of, say, 7 organsiations, each was assigned 1/7 of the this ARGE’s funding). Though unsatisfactory, this seems superior to attributing the whole amount to the consortium’s leader only (besides, this affected but a small share of the total amount).

Figure 4:PV of subsidies to single firms and consortia (ARGE), 1995-2006



Source: FFG; own calculations

1.5. FIRMS AND FUNDING

For the 4,077 “genuine” firms, a total of almost 16,000 annual observations is available (on average, about 4 observations per firm). Average turnover is 48 Mio €, with an export share of 36 %; R&D expenditures average 3.2 % of turnover. The firms receive some 50 k€ a year in FFG subsidies (present value), which amounts to 3.3 % of R&D expenditures (or 0.1 % of turnover). By firm size, however, these values are quite heterogeneous:

Table 2: key variables by firm size class; cumulated 1995-2006

size class	# firms	# firm-year data	# obs / firm	turnover	PV of funding	PV / firm	export share	R&D / turnover	PV / R&D	PV / turnover
<10 emp	1,737	5,042	2.9	1,553	26,548	5	19	3.1%	10.8%	0.34%
10-25 emp	640	2,570	4.0	2,998	40,448	16	29	5.9%	8.9%	0.53%
25-50 emp	423	1,820	4.3	5,651	40,523	22	35	4.5%	8.8%	0.39%
50-100 emp	394	1,756	4.5	12,732	60,119	34	45	3.4%	7.9%	0.27%
100-250 emp	446	2,198	4.9	30,566	112,603	51	50	3.0%	5.6%	0.17%
250-500 emp	222	1,216	5.5	64,049	102,677	84	59	3.0%	4.4%	0.13%
500-1000 emp	118	716	6.1	146,963	145,510	203	67	3.1%	4.5%	0.14%
>1000 emp	97	607	6.3	760,019	262,222	432	61	3.2%	1.8%	0.06%
total	4,077	15,925	3.9	47,711	790,648	50	36	3.2%	3.3%	0.10%

Source: FFG; own calculations

Most firms belong to the smallest category; only about 22 % have more than 100 employees. Data quality is highly correlated with firm size: for the largest firms, more than twice as many observations (6.3) are available than for the smallest (2.9). Also, export share is positively correlated with firm size (from 19 to 67 %), as of course are all monetary variables. R&D as a share in turnover, however, shows a peculiar pattern: it is largest for firms with 10-25 employees (5.9 %) and lowest for firms from 100-500 employees (3.0 %). For larger firms, this share rises somewhat, to 3.2 %.

The relative importance of FFG funding is negatively correlated with firm size: for the smallest firms, it accounts for 11 % of R&D expenditures, dropping to less than 2 % for the largest firms. As a percentage of turnover, this pattern is even more pronounced, accounting for 0.53 % in the case of second-smallest size class, and for only 0.06 % for the largest. Nevertheless, large firms account for an enormous share of FFG funding: of the 790 Mio € which could be matched to firm data, a third goes to the very largest firms. Firms with fewer than 100 employees accounted for only two fifths of total funding's present value[12].

1.6. 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 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.

[12] Some care has to be taken in the interpretation of these numbers: this does not necessarily mean that firms with fewer than 100 employees received 21 % of the FFG funds, but rather that they received 21 % of those funds which could be matched to firm-level data (recall the difficulty with the matching of firm- and project-level data!).
The 790 Mio which could be matched to firm-level data are a subset of the total funds contained in the project-level data base, which amount to 1,800 Mio € (the difference was either awarded to non-entrepreneurial organisations, like academic or pure research institutions, or could not be matched to firm-level data, as no such data were available for the funding years.

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.

The basic model, then, is

$$\log(R\,\&\,D_{i,t}) = \lambda \log(R\,\&\,D_{i,t-1}) + \alpha \log(PV_{i,t}) + \sum_{k=1}^{4} \beta_k \log(X_{i,t}) + \sum_{t=1998}^{2005} Dt + \gamma_i + \varepsilon_{i,t}$$

Present R&D expenditures are modelled as a function of lagged R&D expenditures (not least to allow for a typical R&D project’s disregard of the calendar year), the present value of present subsidies, a vector with firm characteristics, year dummies, and, lastly, a firm-specific effect. The model is estimated in logs to account for heteroscedasticity introduced by the wildly varying firm sizes (from “one-man-shows” to multi-nationals).

Firm characteristics which were included in the model are turnover (plus square of turnover) and employees (both in logs). Higher lags in R&D and funding were tried, but turned out insignificant (plus, they did not much change the results).

The model was estimated for the years 1997-2005. 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.

The final sample comprised 342 firms, which were selected to represent the “typical R&D performing enterprise”. Therefore, the following criteria were used in selecting these firms from the 4,679 organisations contained in the data base:

- only firms were used in the sample: as mentioned above, a sizable share of all FFG customers consists of academic or non-academic research institutes (which approach the FFG primarily, but not exclusively, via co-operations with partners from industry). Conceivably, such organisations exhibit reactions to R&D support which are quite different from “normal” firms: for the latter, doing R&D is a means to an end (maximising profits), whereas for the former, doing R&D is an end in itself (it is their business to do R&D);
- a minimum of 4 firm-data observations in 1997-2006, 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;
- R&D expenditures which are consistently below 50 % of turnover;
- no “problematic” values of annual turnover. A few firms reported sales which amount to more than a million € 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 2 Mio €/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 FFG. This firm, then, should exhibit R&D expenditures which are about twice the nominal amount of the granted sum (typically, 50 % of project costs are covered by FFG subsidies) and about 4 times the amount of the subsidy's present value (as the typical funding mix consists of grants and loans, the present value, at about 25 % 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 basis.

- two samples were used: "regular FFG customers", with at least 4 years of FFG funding, and "intermittent customers" with 3 years of funding or fewer. The first group contains 342 firms, the second 148.

Although out of a total of 4,679 organisations, a subgroup of 342 (equivalent to about 7 %) might seem small, this selection actually accounts for 45 % of all R&D expenditures and 49 % of funding's PV in the period from 1995 to 2006. The 148 firms of the second group add another 12 % to the R&D expenditures and 16 % to the PV covered in this analysis.

The following table presents the results.

Table 3: estimation results

dependent variable: log(R&D) estimation period: 1997-2005						
	(1)		(2)		(3)	
estimation method	OLS		GMM		GMM	
log(R&D$_{-1}$)	0.3706	(0.02)	0.2949	(0.01)	0.0553	(0.00)
log(PV)	0.0478	(0.01)	0.0480	(0.01)	0.0917	(0.00)
log(turnover)	-0.1585	(0.05)	0.2871	(0.07)	0.0746	(0.04)
log(turnover^2)	0.0142	(0.00)	-0.0119	(0.00)	0.0132	(0.00)
log(employees)	0.2949	(0.02)	0.2052	(0.03)	0.3441	(0.01)
Period dummies and fixed effects (estimation in differences) (standard errors in parentheses)						
# firms	342		342		148	
average PV / R&D	0.037		0.037		0.047	
short-run leverage	1.30		1.30		1.97	
long-run leverage	2.06		1.85		2.08	

Source: FFG data base; own calculations

Column (1) shows the results of OLS regression using the sample of the 342 "regular customers": as the estimation is carried out in logs, the results can be interpreted as elasticities. Thus, a coefficient of 0.0478 on the present value of funding (PV) indicates that a 1 % rise in subsidies leads to a rise in R&D of, on average, 0.0478 %. At the mean of the sample, the ratio of subsidies (present value) to R&D expenditures is 0.037. In the short term (i.e., contemporaneously), the effect of 1 € of additional funding on total R&D expenditures is 0.0478 / 0.037 = 1.30; that is, firms top up each present value-euro of funding with 30 cents of own R&D expenditures. In the long run, the effect is much larger (due to the presence of the lagged R&D term): 0.0478 / (1-0.037) = 2.06. In the long run, firms add one euro of their own to each euro of funding's present value.

This lagged endogenous variable, however, causes OLS to be potentially inefficient, as the lagged value of R&D will be correlated with the error term (as the error term contains a time-invariant, firm-specific component). This may introduce the so-called "Nickel-bias" (see Nickel, 1981), resulting in the coefficient of the lagged endogenous to be estimated too high and the coefficient of the funding too low. A solution has been proposed by Arellano and Bond (1991), who utilize a General Methods of Moments approach (GMM).

The bias will be larger the closer the coefficient of the lagged endogenous variable approaches a value of 1. Although in the present case, this coefficient is estimated at only 0.37, the model is re-estimated using GMM. As instruments, lagged values of R&D (up to lag 2) as well as PV, turnover and employees are used (up to lag 1). The results, reported in column (2), point to a modest Nickel-bias in the OLS regression: the lagged coefficient comes out smaller, even if the coefficient on funding is practically unchanged. Accordingly, the short-term effect is identical, but the long-term effect, at 1.85, is somewhat lower.

Column (3), then, reports the GMM results using the sample of "intermittent customers". The contemporaneous effect is now much larger, at approximately 2 for 1. Long-term effects, however, are almost absent: long-term leverage is almost identical to short-term leverage (2.08 vs. 1.97), due to a lagged R&D coefficient which is close to 0 (but still significant).

Discussion

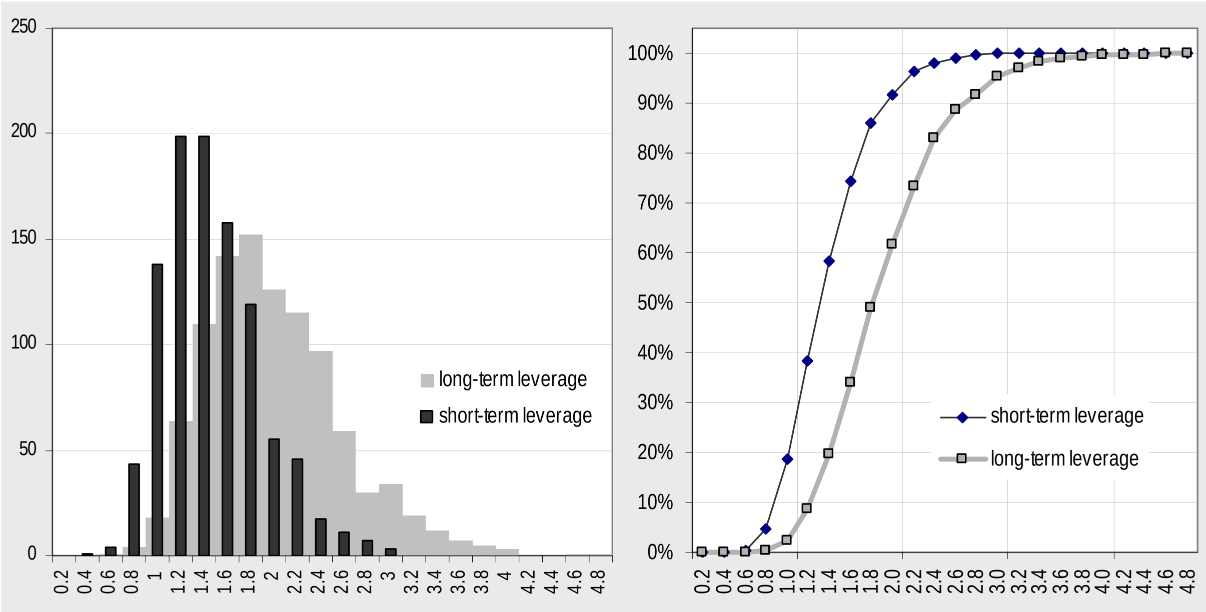
The leverage, at about 80-90 cents of additional own funding for each Euro of subsidies, is sizable, and compares quite well with the effects estimated in other studies (for example, Ali-Yrkkö (2004) estimates 60-86 cents for each Euro in the case of Finnish technology firms. Lach (2000) finds an effect of 40 Cent per Dollar of subsidies to Israeli High-Tech firms; in contrast to FFG funding, where the share of subsidies is about 25 % of project costs, in Lach's case this share is 50 %. On a macro-econometric level, Guellec and Pottelsberghe (2000) estimate 70 cents on average in an analysis involving 17 OECD countries. Also, in a previous analysis of FFG data, Schibany et al. (2004) estimate an effect of 40 cents, which, however, could only be interpreted as the short run effect).

However, though sizable, the leverage falls short of the 3 € which might (naively) be expected given funding policy: remember, present value of funding is typically some 25 % of project costs; therefore, if each approved project were purely additional (meaning that it would not have been carried out in the absence of funding, and that neither acceptance nor rejection of any proposed project would have no repercussions on firms' planned R&D expenditures), each € of funding should lead to a 4 € increase in total R&D expenditures. The estimated effects clearly do not stand up to this "simple" consideration. This is not surprising, given the characteristics of the firm sample used in the estimation (commercial firms, which perform R&D on a regular basis, and which frequently apply for FFG funding): especially in such cases, some degree of windfall behaviour is unavoidable[13]. The somewhat higher effect of intermittent FFG customers also serves to corroborate the suspicion that in some way, regular FFG funding is "factored into firms' R&D plans".

[13] In a survey conducted for the FFF/FWF-evaluation in 2002, a third of applicants to the FFF who were rejected said that they actually dropped the project; of the successful applicants, about a quarter said that they would probably not have pursued their project in the absence of FFF-funding. Conversely, this means that about two thirds of all rejected projects have been pursued even without funding, although probably with some changes (only about 20 % of rejected projects were reported to have been realised as planned).

Another caveat pertains to the numerical value of the leverage effect: this should be taken with a (large) grain of salt. The reason has to do with the observation that the precise results of the regressions quite heavily depend on the specific sample of firms which is used in the estimation process. To appreciate this point, consider the following diagram:

Figure 5:Bootstrap results, N=1000, sample of 342 firms



Source: own calculations

It shows the results of a Bootstrapping experiment: from the original sample of 342 firms, a new sample is constructed by drawing – with replacement! - a new set of 342 firms (which, consequently, will contain some firms more than once, while other firms will not be included in this new sample); the model is then re-estimated on this new set and the estimation results are recorded. This procedure is iterated, say, 1000 times; afterwards, the collected results are statistically analyzed (the Bootstrap is an accepted method to estimate e.g. confidence intervals for unknown distributions).

The left diagram shows the histogram of the 1000 iterations, the right one the cumulative distribution, both for the short- and the long-term leverage. As can be seen, the range of the estimated leverage values is quite large (95 % of the values for the long-term leverage are in the range of 1.0 to 2.2). From this, it seems safe to deduce that the leverage effect is positive (with a leverage value larger than 1.0, more than 97.5 % of the Bootstrap sample exhibit at least modest crowding in), but also that any exact value should be treated with great care.

Additionally, the GMM results are quite sensitive to the set of the instruments used in the estimation process (unfortunately, there is no single “correct set” of instruments), although the similarity of OLS and GMM results – given the relatively small value of the lagged R&D coefficient - might be interpreted as corroborative of the chosen list of instruments.

Yet another point pertains to public funding which does not come from the FFG (and which, accordingly, is not contained in the data base): according to Statistics Austria’s R&D statistic, in 2004 R&D expenditures of business firms (excluding the corporative sector) amounted to 3,200 Mio €, 123 Mio of which were financed by the public sector. Of the public sector, federal, regional and local governments accounted for 16, 22, and 0.3 Mio €, respectively. "Other" public sources, by far the largest share of which is made up of FFG and FWF, accounted for 85 Mio €. In short, public funds accounted for 3.8 % of business firms' R&D expenditures; FFG and FWF accounted for 70 % of public funds (in the case of business firms, FWF funding is negligible, so almost all of this is attributable to FFG funding). Nevertheless, some 30 % of public funding for firms' R&D is not accounted for by our data base. In how far this influences the results is not clear and depends on the correlation with FFG funding: if the other sources of public funds are uncorrelated with FFG funding, our results are largely independent of these funds. A positive correlation, however, would lead our results to be biased upwards (i.e., the "true" coefficients would be smaller); conversely, negative correlation would lead to downward bias. As mentioned, the correlation between FFG funding and other public funding is unknown; at least some sources, however, are certainly correlated (e.g., Carinthia "tops up" FFG funding to the limit allowed by EU law). Therefore, the estimated effects are arguably somewhat too large, although probably not by much.

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