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An Overview of Contemporary Analytical Models

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MEASURING LEVERAGE EFFECTS OF PUBLIC R&D FUNDING

AN OVERVIEW OF CONTEMPORARY ANALYTICAL MODELS

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Abstract:

This survey on contemporary analytical firm-level studies outlines the currently available microeconometric methods of measuring leverage effects of public R&D funding. A comparison of recent company-level studies indicates the difficulties of measuring leverage effects, as the results are inconclusive: roughly half of the studies indicate complemenarity and substitution between public and private funding respectively.

Keywords: R&D Subsidies, Microeconomics, Evaluation Methods, Public Policy Measures

JEL Classification: H40, L10, O30, O31, O38

1 Introduction

This survey is an effort to compile contemporary models on measuring the leverage effects of public R&D funding. As our starting point we take the consensus amongst economists that leaving R&D performance only to private firms without government intervention will result in an under-investment in R&D in terms of desired social returns (cf. Martin and Scott [2000:439]).

Various studies on the R&D spending behavior of firms raise the question 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? Many economists, based on the pioneer work of Blank and Stigler (1957) as well as Griliches (1958), have evaluated the firm behavior on different R&D funding policies. Hence, at the beginning it is necessary to point out our interest in this field.

The 'OECD Working Group on Innovation and Technology Policy' focuses on the new patterns of private and public financing of R&D. In recent publications they indicate considerable evidence of significantly changing business strategies for R&D:

> *"The growing levels of business R&D compared to publicly funded R&D imply that the private sector exerts greater influence over national innovation systems and that governments must better leverage their more limited resources to improve national innovative performance. The changing patterns of business R&D suggest that governments will need to adapt S&T policies to better complement private sector activities and address emergent market failures while avoiding government failures."*
> (OECD [2001:2])

The consequences of the changing environment are our main motivation in surveying analytical models and performing new studies on the efficiency of current public R&D policies. 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. Furthermore the results are often exposed to critique over the expert's objectivity. Second, the group of quantitative research studies, which is organized by the degree of data aggregation. The structuring in line of business, firm level, industry level, and macroeconomic models are the commonly used classification of quantitative research studies (cf. David et al. [2000]).

Macroeconometric models on measuring leverage effects consider aggregate private and public R&D spending variables with limited possibilities to adjust for heterogeneities and asymmetries among firms or interdependence of enterprise behavior in imperfectly competitive markets (cf. David et al. [2000:525-26]). Thus we decided to focus mainly on the evaluation of microeconometric (line of business, firm level, and industry level) models where we can observe the more disaggregated effects, which are vital for adjusting public R&D funding policies.

To cope with the different approaches of recent models a brief outline of various public subsidy instruments and the anticipated firm behavior is given in part 2. In part 3 of this literature survey we are going to present and compare a number of different methods to estimate leverage effects of public R&D spending as well as the key results of these studies.

2 Public subsidy instruments and anticipated firm behavior

We have to bear in mind that different subsidy instruments induce different firm behavior. It is not necessary but seems to be very useful to introduce a classification of used subsidy instruments if we want to pursue with analyzing analytical evaluation models. Fölster (1991) proposes to summarize the instruments in two broad categories: General subsidies and selective subsidies where the latter can be subdivided into non-self-financing and self-financing subsidies. Table 2.1 presents a useful classification. Refering to Fölster (1991) the most common instruments are grants, loans, and tax deductions. However all subsidy instruments are in use somewhere and are not only theoretical applications.

Table 2.1: Classification of subsidy instruments

General subsidies	Selective non-self-financing subsidies	Selective self-financing subsidies
Tax deduction for R&D expenses	Project grants	Fee-bases loan guarantees
Tax deduction for a rise in R&D expenses	Project loans at subsidized interest rates	Royalty grants. Royalty to the state is based on sales of the invention toward which the grant was applied
Personnel grant toward costs of R&D personnel	Conditional loans that are repaid only if R&D is successful	Stock option grants. In return for an R&D grant the state receives a stock option that can be exercised if the stock value rises significantly.
	Loan guarantees	Convertible loans. The state gives a loan that can be converted into stock if the project turns out to be a commercial success
	Prizes	Equity investment. The state invests in venture firms either directly or indirectly via private investment companies

Source: Fölster (1991:24)

Besides econometric evidence on the efficiency of subsidy instruments, which we are going to present later, there are several issues important to consider for policy makers. The main differences between the two broad categories of subsidies are discussed below.

General subsidies allow the firm to choose their R&D projects whereas with selective subsidies the government chooses the R&D project to support. Although the bureaucrats want to influence the decision on the performed R&D projects to maximize social returns they often lack market information and hence influence the decision on technological standards. The problem of asymmetric information can be partly reduced by letting the firms bid for the indirect subsidy in a competitive environment to ascertain the firm's internal valuation of a project (cf. Martin and Scott [2000]).

Furthermore the allocation process of general subsidies, like tax deductions or tax credits, is in most of the cases transparent and unbureaucratic. The entry barrier can be kept low which assures the participation of small and medium enterprises (cf. Hutschenreiter and Polt [2001]). A major disadvantage occurs with budgeting the general subsidies, because they can only be estimated through the tax expenses of previous years.

Remember that for each subsidy instrument there are arguments for potential positive as well as negative leverage effects on private R&D spending behavior. Lach (2000) argues for a tendency of complementary as well as substitution effects. He pointed out that on the one hand subsidized R&D can upgrade R&D facilities, which leads to lower fixed costs for future R&D projects and therefore to an increase in the probability of realizing the project. In addition knowledge spillovers from the funded project can increase the probability of success of future projects. On the other hand government bureaucrats are under pressure exhibiting short-term success in allocating public funds, which can lead to a funding of R&D projects with higher success probability. These are projects, which the firm would have undertaken anyway and private expenditures can be crowded out, if they are not invested in other, much riskier R&D projects. Another reason for crowding out could be the effect on the price of R&D inputs, especially the inelastic supply of R&D personnel.

Martin and Scott (2000) approach the problem of a reasonable use of a specific subsidy instrument by analyzing the main mode of innovation. They argue that

> *"Industries differ enough and in sufficiently important aspects that these differences must be taken into account in explaining market performance. This is true for technological performance as well as product market performance in a static sense. With respect to the appropriate institutional framework for public support to investment in innovation, factors to be taken into account are*
>
> - *whether innovation is incremental in nature or takes the form of discrete, fundamental breakthroughs;*
> - *the extend to which patents or other mechanisms allow innovators to appropriate a sufficient share of the profits that results from successful innovation;*
> - *the degree of product-market rivalry;*
> - *the importance of learning-by-doing (if present, R&D is a necessary ticket to enter the market)."*
>
> (Martin and Scott [2000:445])

Table 2.2: Innovation modes, sources of sectoral innovation failure, and policy responses

Main mode of innovation	Sources of sectoral innovation failure	Typical sectors	Policy instruments
Development of inputs for using industries	Financial market transactions costs facing SMEs; risk associated with standards for new technology; limited appropriability of generic technologies.	Software, equipment, instruments	Support for venture capital markets; bridging institutions to facilitate standards adoption
Application of inputs developed in supplying industries	Small firm size, large external benefits; limited appropriability	Agriculture, light industry	Low-tech bridging institutions (extension services) to facilitate technology transfer
Development of complex systems	High cost, risk, limited appropriability (particularly for infrastructure technology)	Aerospace, electrical and electronics technology, telecom/computer technologies, semiconductors	R&D cooperation, subsidies; bridging institutions to facilitate development of infrastructure technology
Applications of high-science-content technology	Knowledge base originates outside commercial sector; creators may not recognize potential applications or effectively communicate new developments to potential users	Biotechnology, chemistry, materials science, pharmaceuticals	High-tech bridging institutions to facilitate diffusion of advances in big reserach

Source: Martin and Scott (2000)

Table 2.2 summarizes innovation modes in four main categories and the respective sources of sectoral innovation failure. The policy instruments are designed in such a way that they overcome the private underinvestment in technology R&D.

3 Analytical Models & Results

Recent years have seen many analytical models on measuring the leverage effects of public R&D spending. The results couldn't be more heterogeneous. Wallsten (2000), for example, uses a three-stage least square firm-level model on SBIR funded companies and shows that public R&D subsidies lead to over 80% crowding out of private R&D spending. Lach (2000), who as well used an econometric model to analyze Israeli manufacturing firms, made the counter argument. He finds a complementary effect on public R&D spending of over 40%. Why do the results of empirical studies on the effects of public subsidies remain so ambiguous?

First we have to explain the major difficulties and obstacles in the model selection process to be able to draw conclusions on different modeling approaches and the yielding results. In designing an econometric framework one has to take account of the relevant risks:

- Public subsidies are not always randomly assigned to the private firms, which implies endogeneity of public funding. Including an endogenous variable in linear regression framework will cause biased estimators if there exits correlation with the regression's error term. It is not unrealistic to assume that for instance public and private expenditure are correlated because firms with an increase in private spending receives subsidies, not because public subsidies caused private R&D spending to increase.
- Neither from a negative nor a positive relationship of public to private R&D spending one can automatically conclude a crowding out or substitution effect. A consistent estimator of the firm's R&D spending performance in absence of a public subsidy is needed to draw reasonable conclusions (cf. Busom [1999]).
- It is important to build a framework on measuring not only a single subsidy instrument at one point in time. Public R&D policies are far-reaching (cf. subsidy instrument above) and proper econometric analyses have to measure the effects of all subsidy instruments simultaneously.
- Considering a static econometric approach, as researchers in this field often pursue it, leaves out the long-term effects of subsidies through the channel of learning-by-doing and spillover effects. The future success of private R&D projects can be affected by past-subsidized R&D projects.

Before we introduce some econometric approaches and results, we first want to point to an example of a qualitative study about leverage effects of different subsidy instruments. Fölster (1991) conducted a survey on 214 (135 from large firms, 79 from small firms) research projects or project proposals amongst Swedish high-level R&D managers to evaluate the leverage effects of a single subsidy (cf Table 2.2). They were asked both on R&D projects carried out and on those that were rejected. The efficiency of a subsidy is defined as the amount of additional private R&D expenditure generated for each invested unit of public R&D spending. The author simulated imperfect information, hence one half of the projects are selected on the criterion that they would not have been conducted or would have generated at least 50 percent of complementary private R&D spending. The other half is selected as though the subsidizing agency had no information about the project and all applying firms would receive the subsidy. Table 3.1 presents the ratio of additional private R&D spending generated by each single subsidy instrument.

General subsidies induce an increase of private R&D spending in large firms of only 16-19% percent, whereas this effect is only 7-8% for small firms. The most effective instruments are the self-financing subsidies. Stock option grants and royalty grants show the highest complementary effects amongst the groups of large and small firms. The reason might be that firms would not have conducted the projects in absence of these specific subsidy instruments, thus making carry-over effects very small. Overall it is observable that smaller firms generate more additional R&D expenditure through public subsidies than large firms. A crowding out effect, which would be indicated by a negative ratio, does not exist for any of the subsidy instruments.

Table 3.1: Ratio of R&D generated by the subsidy with imperfect project information

	Large firms	Small firms
1. Tax incentive	0.19 (0.06)	0.08 (0.07)
2. Grant to R&D personnel	0.16 (0.06)	0.07 (0.07)
3. Project grants	0.41 (0.06)	0.52 (0.07)
4. Project loans	0.40 (0.05)	0.59 (0.07)
5. Conditional loans	0.47 (0.06)	0.64 (0.08)
6. Fee-based loan guarantees	0.48 (0.01)	0.47 (0.02)
7. Royalty grants	0.56 (0.10)	0.74 (0.11)
8. Stock option grants	0.72 (0.09)	0.92 (0.10)

Standard errors are shown in parentheses

Source: Fölster (1991:84)

The results of the qualitative study doesn't only leave us with interesting questions but also gives as an impression on what econometric models should be able to achieve. In a next step we are going to summarize microeconometric models of Lach (2000), Czarnitzki and Fier (2001), Irwin and Klenow (1995), Klette et al. (2000), Wallsten (2000), and Busom (1999).

David et al. (2000) worded a very accurate explanation of what these models try to accomplish:

> *"The typical econometric approach is to regress some measure of private R&D on the government R&D, along with some 'control' variables. When a positive coefficient on the public R&D variable is found, this is interpreted as revealing the predominance of complimentary between private and public investments. On the flip-side, a negative coefficient is taken to imply that public R&D and private R&D are substitutes"* (David et al. [2000:510]).

Even stated as simple, we want to gain deeper insight by looking at different models.

3.1 ISRAELI MANUFACTURING FIRMS: LACH (2000)

Lach (2000) analyses the effect of an R&D subsidy on private R&D spending of Israeli manufacturing firms. The observation period from 1990 to 1995 includes approximately 180-190 firms per year. The used data set on R&D subsidies bases on the grant statistics of the Office of Chief Scientist (OCS) and some other smaller government agencies. Subsidies given by the OCS vary between 30 and 66 percent of the total R&D expenditures for a project (30% for improving an existing product, 50% for creating a new product or industrial process and 66% for projects of start-up companies). The OCS is obligated by law to subsidize all eligible projects. The data set contains firm level data but it is not possible to distinguish between firms whose proposal was rejected and firms that didn't apply for a subsidy.

Lach (2000) presents an analytical step-by-step approach to explore various channels through which a public subsidy affects the firm's decision process. We want to acknowledge the structured work by presenting the key steps and results of his work.

The Simple Difference Estimator

The framework of the model starts out with a straightforward approach of the simple difference estimator. The estimator $\hat{\alpha}$ is the difference of the mean private R&D expenditure ($\bar{y}_t^{D_{t-1},D_t}$) of two groups where the one group received a subsidy at time t ($\bar{y}_t^{01}$) and the other did not ($\bar{y}_t^{00}$), given that they were both not subsidized in $t-1$.

$$\hat{\alpha}^D = \bar{y}_t^{01} - \bar{y}_t^{00} \tag{1}$$

$$E\left(y_{it}^0 \middle| D_{it} = 1, D_{it-1} = 0\right) = E\left(y_{it}^0 \middle| D_{it} = 0, D_{it-1} = 0\right) \tag{2}$$

In accordance with equation (2) α is a consistent and unbiased estimator only if y_{it}^0 is independent of D_{it}. In the sample of Israeli firms the R&D subsidy appears to have no significant effect on private R&D expenditure, given that the estimator is unbiased. But it is further shown that α cannot be unbiased if the subsidies are not randomly assigned to the firms. This is only the case if *"there are no common or correlated factors determining the probability of receiving a subsidy and the level of R&D expenditure.* [The assumption] *is overly strong and is bound to fail in the data"* (Lach 2000:18).

The Simple Difference Estimator Conditional on Covariates

Accounting for the differences in private R&D expenditure by using all firm characteristics (x is a vector of covariates) extends the model to

$$E\left(y_{it}^0 \middle| x, D_{it} = 1, D_{it-1} = 0\right) = E\left(y_{it}^0 \middle| x, D_{it} = 0, D_{it-1} = 0\right) \tag{3}$$

where the inclusion of x leaves the question whether a firm is selected in the subsidy program or not independent of y_{it}^0. An OLS regression of the form

$$y_{it} = x_{it}'\beta + D_{it}\alpha + \varepsilon_{it} \tag{4}$$

makes the estimation of α possible.

Lach (2000) includes industry affiliation, employment size and sales as firm characteristics to correct for the possible bias in receiving public funding. His results, using the firm characteristics, get more precise but are still insignificantly different from zero. It is very likely that not all firm characteristics can be captured since it is almost impossible to know all factors correlated with the probability of receiving an R&D subsidy.

Difference in Differences (DID) estimator

Further, Lach (2000) suggest using a Difference in Differences (DID) estimator to overcome the above-quoted problem. The error term ε_{it} of equation (4) is, due to the potential correlation, decomposed into a firm-specific (θ_i) and a time-specific (λ_t) effect. That leaves η_{it} in equation (5) as an i.i.d. zero mean error term.

$$y_{it} = x'_{it}\beta + D_{it}\alpha + \theta_i + \lambda_t + \eta_{it} \qquad (5)$$

Again consider only firms without subsidy in *t-1* and taking the first differences results in,

$$\Delta y_{it} = \Delta x'_{it}\beta + D_{it}\alpha + \Delta\lambda_t + \Delta\eta_{it} \qquad (6)$$

The model now allows for "firm specific unobserved effects and economy wide shocks to affect both the level of company-financed R&D expenditures and the support status of the firm." (Lach 2000:21)

The Difference-in-Differences (DID) estimator with covariates in equation (7) may overcome the problem that the characteristics of a subsidy-receiving firm might be correlated with the firm's changing R&D expenditure. Lach (2000) proceeded with explaining that the DID estimator accounts for common observed covariates and permanent differences between applicants, but cannot explain factors which affects both the level of R&D expenditure and the probability of receiving a subsidy simultaneously.

$$\hat{\alpha}^{DID} = \left(\bar{y}_t^{01}(x_t) - \bar{y}_{t-1}^{01}(x_{t-1})\right) - \left(\bar{y}_t^{00}(x_t) - \bar{y}_{t-1}^{00}(x_{t-1})\right) \qquad (7)$$

To improve the precision of the estimator (the samples are otherwise getting too small) Lach pooled the data over the 5 years using only observations for which $D_{it-1} = 0$. He also accounts for the fact that subsidies are usually given to firms over a period longer than one year and hence one lag of D_{it} is added to the model. The results are presented in Table 3.2.

Table 3.2: Pooled DID Estimates of a, 1990-95, Equation (5)

Variable	Coefficient
$D_t = 1$	-0.299 ** (.168)
$D_{t-1} = 1$	0.378 * (.190)
Employment	-0.108 (.239)
Sales	0.285 (.208)
Within R^2	0.087
N (firms)	214 (103)

*Standard errors in parentheses. Year dummies included. */** indicates different from 0 at 5% /10% significance level. Firms only used with $D_{it-2} = 0$.*

Source: Lach (2000:24)

Public subsidies crowd out private expenditure by almost 30% but this effect is reversed if the firm is subsidized more than one year. A complementary effect of 38% percent is measured in the follow up year, which leaves a net complementary effect of only 8% (standard deviation of 75 percent). The parameters are still not significantly different from zero, thus Lach pursued with the development of the model framework.

Dynamics and the Effect of the Subsidy Level

Lach pursued his work by extending equation (5) using *q* lags of the log of the amount of subsidies (s_{it}). To capture the dynamic effects the subsidy level replaces the binary variable D. The author argues that a dynamic framework takes account of the effects on R&D expenditure, especially if a time lag in the impacts is observable.

$$y_{it} = x'_{it}\beta + \sum_{\tau=0}^{q} \alpha_\tau s_{it-\tau} + \theta_i + \lambda_t + \eta_{it} \quad (8)$$

Table 3.3 presents the results for a GMM estimation with a lag of one period. The OLS coefficient of s_{t-1} is small but statistically significant. Factoring out the firm-specific effects using a within estimator leads to a smaller coefficient. Still, we can conclude that there is a small but significant positive effect on the lagged subsidy level.

"Although significantly positive, the subsidy effect is substantially lower what could havebeen expected a-priori given the dollar-by-dollar matching upon which most subsidies are based. The reasons for this "less than full" effect lie in that the subsidies are sometimes granted to projects that would have been undertaken even without the subsidy, and in that firms adjust their portfolio of R&D projects–closing or slowing down non-subsidized projects–after the subsidy is received." (Lach [2000:31])

Table 3.3: Estimates of the subsidy level effect, (q=1)

Coefficient of	OLS	Within	First Δ	First Δ
y_{t-1} (ρ_1)	0.779* (.035)	0.082 (.050)	-0.029 (.140)	-0.003 (.123)
s_t (δ_0)	-0.006 (.017)	-0.024 (.021)	-0.080 (.064)	-0.119** (.063)
s_{t-1} (δ_1)	0.054* (.016)	0.044* (.016)	-0.089 (.057)	-0.061 (.051)
Employment	0.139* (.053)	0.233** (.141)	0.202 (.321)	0.243 (.297)
Sales	0.053 (.044)	0.130* (.052)	-0.222 (.140)	-0.181 (.131)
m_1	-2.87	-3.96	-0.96	-1.29
m_2	0.75	-0.26	-0.75	-0.52
Instruments	–	–	A	B
Sargan test	–	–	0.80 (35)	0.91 (45)
N (firms)	766 (221)	545 (193)	545 (193)	545 (193)
Years	1991-1995	1992-1995	1992-1995	1992-1995

Industry and year dummies included. Asymptotic robust standard errors in parentheses.

Source: Lach (2000:28)

3.2 GERMAN SERVICE FIRMS: CZARNITZKI AND FIER (2001)

Czarnitzki and Fier (2001) analyze whether public research funding sustainably enforce the innovative activity of German service firms. In addition they ask if future access to public R&D funding schemes is affected by current participation in a public R&D program. The used data set contains a sample of 2,541 observations of the German service sector, from which 137 are associated with an R&D subsidy. To keep with the international standards the authors use the definition of innovation expenditure of the OSLO-manual.

Innovation intensity (*InnoInt*) on the firm level is defined as the ratio of innovation expenditure and sales, whereas public funding intensity (*PFInt*) is the ratio of the sum of public subsidies over the past five years divided by the sales. The lags are included to account for the length of research projects. Hence subtracting public R&D funding intensity from innovation intensity composes a net innovation intensity indicator (*NetInnoInt*). The authors use this indicator to measure the correlation of past public R&D subsidies to current private R&D expenditure. In the case of a positive correlation past public R&D subsidies would have a positive impact on current private R&D spending.

Czarnitzki and Fier (2001) estimate an OLS-model by regressing net innovation intensity on public funding intensity and several control variables

$$\begin{aligned} NetInnoInt_{it} &= \alpha_i + \beta_1 PFInt_{it} + \beta_2 EMP_{it} + \beta_3 EMP_{it}^{\;2} + \beta_4 EAST_i + \beta_5 AGE_i^{\;-1} \\ &+ \beta_6 EX_{it} + \beta_7 DIV_{it} + \beta_8 GRFF_{it} + IndustrieDummies + \varepsilon_{it} \end{aligned} \tag{9}$$

where EMP = Employment, $EAST$ = Dummy for firm location in Eastern Germany, AGE = Firm age, EX = Export to sales ratio, $GRFF$ = Sectoral dynamics indicator, DIV = Firm diversification index

Table 3.4: OLS regression on public funding intensity

	Dependent variable:	
Exogenous variables:	NetInnoInt	NetInnoInt
PFInt	1.37 ** (2.08)	
PFInt (lagged)		1.26 ** (2.00)
1/AGE	15.05 *** (3.53)	15.03 *** (3.52)
GRFF	9.37 *** (2.92)	9.48 *** (2.94)
Joint significance of EMP and EMP^2	13.46 ***	13.49 ***

*t-values are shown in parentheses, significance levels: ***/**/*=1/5/10%,*
estimation as in equation (9), coefficients only shown if statistical significant.

Source: Czarnitzki and Fier (2001:10)

Table 3.4 shows the results of the OLS regression. The public funding intensity coefficient is significant at the 5% level, whereas the degree of competition, measured by the sectoral dynamics, as well as the firm age coefficient are significant at the 1% level. Putting the numbers in words would lead to the following key results:

- They find that one unit of public R&D subsidies leads to an increase in private R&D funding of 1.37 units in the following time period.
- Conducting the regression with a time lag of one year on public funding intensity shows the effect over time. If the subsidy was granted a year ago the leverage factor decreases to 1.26.
- An increasing competition leads to an increase in private R&D spending.
- Younger firms are more innovative than old firms. *"We confirm this hypothesis of innovative start-ups in the service sector"* (Czarnitzki and Fier [2001:9]).
- The two employment variables are insignificant individually, but jointly significant at the 1% level. *"Large companies invest relatively less in innovative activity than smaller ones"* (Czarnitzki and Fier [2001:9]).
- All other firm specific variables have no statistically significant effect on innovation intensity.

3.3 US-SEMATECH FUNDED HIGH-TECH FIRMS: IRWIN AND KLENOW (1995)

In 1987 the US government initiated Sematech with the primary goal to improve the US semiconductor production technology. The consortium was founded by 14 high-technology firms and they received annually ARPA funding of up to $100 million in matching funds since 1997.

Irwin and Klenow (1996) used annual firm-level data for the period 1970-93 to evaluate the US research consortium Sematech. They compared the research effort of Sematech members with non-member firms controlling for firm fixed effects, time effects, firm age effects, and past R&D intensity.

$$\left(R\ \&\ D/Sales\right)_{it} = \beta_1 Sematech + \beta_2 \left(R\ \&\ D/Sales\right)_{it-1} + Dummies + \varepsilon_{it} \qquad (10)$$

They present results for two time periods (1970-1993, 1980-1993) with OLS and WLS estimates. The chosen weights for the WLS estimation were firm-year assets. Sematech is a dummy variable for participation in the project, all other dummies are mentioned above. The estimated coefficients are given in Table 3.5.

Table 3.5: Sematech membership and R&D expenditure

Exogenous variables:	Dependent variable: R&D/Sales			
	OLS (1970-93)	WLS (1970-93)	OLS (1980-93)	WLS (1980-93)
Sematech	-1.30 (0.49)	-1.02 (0.33)	-1.83 (0.60)	-1.84 (0.49)
Lagged R&D/Sales	0.43 (0.06)	0.57 (0.05)	0.20 (0.07)	0.34 (0.06)
Age≤2	7.0 (2.4)	3.6 (2.4)	5.3 (1.2)	2.8 (2.2)
3≤Age≤5	9.8 (2.3)	5.8 (1.9)	7.8 (1.4)	6.1 (1.4)
Age≥6	10.5 (2.2)	6.5 (1.9)	8.6 (1.4)	6.3 (1.2)
Unweighted R^2	0.78	0.75	0.77	0.75

Standard errors in parantheses, results in percentage terms, firm and year effects included

Source: Irwin and Klenow (1996:334)

As the results are given in percentage terms the interpretation is straightforward. Sematech member firms' R&D intensity decreased by 1.3 and 1.0 percentage points for the period 1970-93 and by 1.8 percentage points for the shorter period 1980-93. In terms of overall private R&D spending 9Irwin and Klenow (1996) estimated a reduction of $300 million per year amongst Sematech members.

Klette et al. (2000) point out that the validity of the control group is rather problematic:

"Comparing the list of Sematech member firms to the non-member US firms, it is clear that the Sematech-members are the leading US manufacturers in the electronic components industry, and this was true also when Sematech started." (Klette et al. [2000:74]).

Beside the well know sample selection bias another drawback was pointed out. The public subsidy program Sematech, designed for a small number of high-technology firms, may have increased or decreased the R&D effort of competitors which were non-members. Comparing therefore the relative R&D spending of members and non-members can lead to bias results.

3.4 THE PROBLEM OF THE COUNTER FACTUAL: KLETTE ET. AL (2000)

Klette et al. (2000) did not estimate an econometric R&D-model, but rather approached the problem from a theoretical point of view. Many economists have identified a potential selection bias and the problem of the counterfactual but eventually only few have incorporated these problems in their models. Hence, we think it is very important to present the work of Klette et al. (2000) in a detailed form.

The performance of a firm i in period t is represented by

$$Y_{i,t} = \alpha_i + \lambda_t + \beta_i D_i + u_{i,t} \qquad (11)$$

where D_i is a dummy variable (one if firm received R&D funding, zero otherwise), α_i a firm fixed effect, λ_t are shocks common across firms, and u_{it} temporary fluctuations in unobservables.

The difference-in-differences estimator, given that firm-level data exist for the ex-ante and ex-post case, enables us to measure the average impact of R&D funding on the firm.

$$\hat{\beta}_{did} = \left(\overline{Y}_{t_1}^{s} - \overline{Y}_{t_0}^{s}\right) - \left(\overline{Y}_{t_1}^{n} - \overline{Y}_{t_0}^{n}\right) = \Delta\overline{Y}^{s} - \Delta\overline{Y}^{n} \qquad (12)$$

The estimator is the difference between the average change of the firm performance in the supported and the non-supported case. If we take the assumption that D_i and u_{it} are uncorrelated we get

$$p\lim_{n\to\infty} \hat{\beta}_{did} = E\left(\beta_i \middle| D_i = 1\right) \equiv \beta^{S} \qquad (13)$$

which is the mean impact of the treatment on the treated. As many economists have argued there remains the problem of a correlation between the shocks u_{it} and the probability of being selected in a subsidy program. Klette et al. proceed suggesting to implement variables, which correct the DID-estimator for the pre-program performance as well as variable to control for anticipated temporary shocks that influence the probability of being selected in a subsidy program.

In addition, Klette et al. suggest taking account of spillover effects from subsidized to non-subsidized firms. It is very unlikely that the performance of the non-subsidized firms is independent of the public R&D programs, particularly as most programs are designed to generate maximum spill over effects. To describe the situation best Klette et al. refer to the Catch-22[1] problem: *"If the program is successful in creating innovations that spill over to technologically related firms, it will be very difficult to find similar non-supported firms that can identify the counter factual outcome for the supported firms."* (Klette et al. [2000:481])

Since we are trying to evaluate post-program performance or research intensity of firms who have been subsidized to overcome the problem of the counter factual by matching firms with the same 'fundamentals' the problem gets even worse. Klette et al. indicate that *"[...] the better a firm seems to*

[1] Catch-22:
"In Joseph Heller's novel Catch 22, published in 1961, the catch in question was that airmen could be excused from flying missions only if they were of unsound mind, but a request to be excused from flying missions was a sign of a concern for personal safety in the face of danger and therefore evidence of a rational mind, so it was impossible to escape flying missions. A catch-22 situation is any such circular dilemma or predicament from which there is no escape, and is often extended to any situation or problem where the victim feels that it is impossible to gain a personal benefit or make the right decision."
Source: Bloomsbury Good Word Guide, Bloomsbury 1997

satisfy the conditions required to identify the counter factual outcome in the absence of spillovers, the worse might this spillover problem be." (Klette et al. [2000:482])

To conclude, the authors stress that even if an evaluation study finds little difference between subsidized and non-subsidized firms either be because the public R&D program was unsuccessful, or because it was successful in generating very high spillover effects to the non-subsidized firms.

3.5 US-SBIR FUNDED TECHNOLOGY-INTENSIVE FIRMS: WALLSTEN (2000)

The Small Business Innovation Research (SBIR) program consists of three phases to which firms can apply. Phase one awards a maximum of $100,000 and only if the firm wins this award it can apply for phase 2 with a maximum subsidy of $750,000. In phase 3 the resulting product should be commercialised and no funding is distributed. Wallsten (2000) assembled a data set with firms who received awards (367 firms), firms who were rejected (90 firms) and firms who didn't apply but were eligible (22 firms). The selected industry was a group of small technology intensive companies. The observation period was from 1990 to 1993. Due to data restraints, the author observed only short- and medium term effects.

Wallsten (2000) points out the importance of controlling for endogeneity of awards. The standard OLS regression shows a significant correlation between e.g. employment and receiving an award. His solution provided is to simultaneously estimate a system of equations using the instrument variable approach. As the instrument variable, Wallsten used the SBIR total budget. Besides the results on the effects of SBIR funding on firm performance, he also estimated the relationship between firm-financed R&D and public financed R&D. The results are shown in Table 3.6.

Table 3.6: 3-SLS Estimates: Effect of SBIR-$ on firm-financed R&D spending

Dependent variable	Total $-value of SBIR awards	R&D spending in 1992
Constant	69,432 (0.23)	2,733,110 (2.02)
Total $-value of SBIR awards		-0.82 (2.31)
SBIR budget instrument	2.96 (11.58)	
Age	-12.78 (1.58)	
$Employment_{1991}$	736.70 (0.37)	-2,195.79 (0.25)
$Patents_{1988-1989}$	111,128 (2.00)	381,841 (1.62)
R&D $spending_{1990}$	-0.14 (3.25)	1.01 (4.90)
Never applied		-1,806,970 (2.38)
R^2 (81 observations)	0.80	0.71

Absolute t-statistics in parentheses

Source: Wallsten (2000:98)

The private R&D spending coefficient of the three-stage least-square estimation, with the total dollar value of SBIR awards as endogenous variable, is estimated at -0.82. This can be interpreted as a decrease of 0.82 units in private R&D spending for each unit of public R&D subsidy. Wallstein (2000) points out how important it is to control for endogeneity and to use an instrument variable approach.

"One interpretation of the empirical results is that the awards have no impact on firm R&D activities. They simply crowd out firm-financed R&D expenditures [...]. This is not the only interpretation, however. Another possibility is that while the grants did not allow firms to increase R&D activity, they instead allowed firms to continue their R&D at a constant rate rather than cutting back. That is, while the grants may not have funded additional projects, they may have allowed firms to avoid eliminating ongoing projects." (Wallsten [2000:98])

One last caveat: It may be possible that the effect of SBIR awards could materialize in the future, which, due to data constraint, can not be explored.

3.6 EFFECTS OF R&D SUBSIDIES IN SPAIN: BUSOM (1999)

Busom (1999) analyzes firm data of 154 Spanish firms conducting R&D activities in 1988. Almost half of the firms in the sample received public subsidies by the Spanish authorities. The selected firms were then asked a set of questions to complement the data of the Spanish Ministry of Industry.

Table 3.7 shows the definitions of the binary and continuous variables for the forthcoming regression analysis.

Busom (1999) then constructs a framework to measure the leverage effects of public subsidies in Spain. First a firm has to decide whether to apply for a subsidy or not, second the public agency decides whether to grant the subsidy or not. These "demand and supply functions" are shown in equation (13) and (14). Equation (15) and (16) describe the effort decision of the firm, dependent on the participation status.

Busom's Analytical Framework:

Variables in capital letters are vectors of explanatory variables. Those in lower case letters are error terms with possible unobservable characteristics of the firm. A^* represents the expected profitability of an R&D subsidy, G^* is the variable of the funding decision of the public agency. $y^*_{1,2}$ is the R&D effort measured in R&D investment or R&D personnel, which is observed both for participating or non-participating firms. A^* and G^* are unobservable for the researcher.

$$A^* = f_a(Z,u), \qquad (14)$$

where the explanatory variables for the probability of applying are defined as firm size, capital ownership, importance given to R&D in the short run, pricing strategy, share of exports in total sales, R&D process indicators, and industry dummies.

$$G^* = f_g(W,v), \qquad (15)$$

where the explanatory variables for a selection criterion are defined as number of patents, age of the firm, firm size, presence of public of foreign capital, and industry dummies.

$$y_1^* = h_1(X_1, w_1) \qquad (16)$$

$$y_0^* = h_2(X_0, w_0) \qquad (17)$$

where the explanatory variables for the effort decision are defined as total employment, strategy and ownership indicators, share of export over total sales, and industry dummies.

Additionally the participation in the program can be observed:

$$I = g(Z,W,u,v) \text{ where } I = 1 \text{ if } A^* > 0 \text{ and } G^* > 0 \text{ and } I = 0 \text{ otherwise.} \qquad (18)$$

Table 3.7: Definitions of the variables constructed from the survey

Binary Variables	*Definition*
Subsidies	
Cdti	=1 if a firm received a subsidy from CDTI; 0 otherwise.
European	=1 if a firm was a partner in EUREKA or any EC R&D program.
Ownership	
Public	=1 if firm was partly publicly owned
Foreign	=1 if firm was participated by foreign capital
Strategic Variables	
Price	=1 if firm declared to set prices and then adjust production to sales
Quantity	=1 if firm declared to make production plans and then adjust prices
Regulated	=1 if firm declared prices to be regulated
Other	=1 if none of the above
Monopoly	=1 if firm declared behaving as such
Frival	=1 if firm declared it would increase own R&D in response to a rival's
Shortrun	=1 if firm declared R&D to be important in the short run
R&D Process	
Ideariv	=1 if firm looked into competitor's products for ideas for own R&D
Ideapt	=1 if firm used own patents as sources of ideas
Ideaext	=1 if firm declared scientific and technical publications to be important
Cooperate	=1 if firm cooperated with others in R&D activities
Basic	=1 if firm does basic or applied research
Development	=1 if firm does development
Process	=1 if R&D activities are oriented towards process innovation
Product	=1 if R&D activities are oriented towards product innovation
Industry	
Dchemical	=1 if firm is in chemical or pharmaceutical industry
Detronics	=1 if firm is in electrical o electronics industry
Dequipmt	=1 if firm is in machinery or transportation equipment industry
Denergy	=1 if firm is in the energy sector
Dtraditional	=1 if firm is in textile, food, metal industries
Dservices	=1 if firm provides services to other industries
DotherI	=1 if firm is in other industries
Continuous Variables	
Patents	Number of patents obtained by firm during the previous 10 years
R&D expenditure	Total R&D expenditure in 1987, in Million pesetas
R&D personnel	Number of employees involved in R&D activities
Age	Number of years since firm was created
Employment	Total number of employees
Exportshare	Exports/total Sales

Source: Busom (1999:12)

In a first step, Busom (1999) estimates a discrete choice model of participation solved with a simple univariate probit regression.

Table 3.8 shows the results for a model with all explanatory variables (Model 1), with only statistically significant explanatory variables (Model 2), and with an additional variable of the short run importance of R&D whilst industry dummies were dropped (Model 3). Columns 4 and 6 show the marginal effect of each variable on the probability of being a participant.

Table 3.8: Probability of the participation in the national R&D subsidy program

	Model 1	Model 2	Marginal Effects	Model 3	Marginal Effects
Constant	-0.61 (-1.2)	-0.39 (-0.9)		-0.67 (-1.4)	
Employment	-0.29 (-3.2)	-0.30 (-3.3)	-0.12	-0.30 (-3.3)	-0.12
Age	0.52 (2.7)	0.54 (2.9)	0.21	0.57 (3.1)	0.23
Exportsh	-0.01 (-0.1)				
Patents	0.44 (3.7)	0.46 (4.0)	0.18	0.45 (3.9)	0.18
Public	0.64 (1.7)	0.55 (1.5)	0.22	0.67 (1.8)	0.27
Foreign	-0.91 (-2.9)	-0.76 (-2.7)	-0.30	-0.79 (-2.8)	-0.32
Price	0.31 (1.1)				
Regul	-0.10 (-0.2)				
FRival	0.26 (0.3)				
Dchemical	0.50 (1.4)	0.50 (1.6)	0.20		
Detronics	0.51 (1.5)	0.51 (1.5)	0.20		
Dequipment	-0.09 (-0.4)				
Denergy	0.24 (0.4)				
Shortrun				0.54 (2.0)	0.22
LogLikelihood	-75.5	-76.9		-76.9	
Restricted L	-101.8	-101.8		-101.8	
X^2	52.5	49.6		49.7	
Pseudo R^2	0.26	0.24		0.24	
N	147	147		147	

t-values are shown in parentheses
Quelle: Busom (1999:31)

Busom's (1999) models 3 and 4 correctly predict 80% of participants and 70% of non-participants. The author found only six factors, which had a significant effect on the probability of having a public subsidy. The positive effects found to be public participation in the ownership, being in the chemical or pharmaceutical sector, age of the firm, and number of previous patents. Large firms size and foreign capital decrease the probability of having a subsidy.

In a next step Busom (1999) asks two questions:

- "does participation induce a higher R&D effort than would have been made otherwise?"
- "does participation make the firm's choice of R&D effort less conditioned by factors such as firm size?" (Busom [1999:21])

As dependent variables R&D expenditure, R&D expenditure per employee, R&D personnel, and R&D personnel per employee are selected to measure firm's R&D effort. R&D expenditure includes the subsidy itself, but information about the subsidy is limited to the binary variable (either subsidy received or not received). Busom (1999) estimates each of the four equations by four different econometric methods:

1. An OLS regression for the whole sample, assuming the group of participants and non-participants can be described by the same coefficients and no subsidy selection/participation bias exists,
2. An OLS regression with a split sample, which allows different coefficients for the two groups but exogeneity of selection/participation is still assumed,
3. A Heckman two step procedure, to correct for the subsidy selection/participation bias, and a
4. Maximum likelihood estimation.

Table 3.9 shows the results for the four procedures where R&D expenditure is used as dependent variable, omitting other measures of R&D effort (see above) because the results vary only slightly (cf. Busom 1999).

Using a chow test to test for equality of slopes between the group of participants and non-participants leads to a rejection according to Busom (1999). The OLS regression for the full sample shows similar results as Heckman's two step procedure. A firm's R&D expenditure, given that the firm does not receive public subsidies, is positively explained by firm size and by either being in the chemical/pharmaceutical or electrical/electronic industry. All other variables have no significant effect on the level of R&D expenditure. For the group of participants positive effects on R&D expenditure are being in the equipment/service industry, having a history of patenting, and an orientation to the domestic markets.

In the last part of her paper Busom (1999) test the presence of crowding out effects of public R&D subsidies. A counterfactual for subsidized firms is constructed by using the estimated effort of non-particpants. The results for individual firms can be summarized as follows:

- 29 firms would have spend at least as much as in the case of no subsidy
- 41 firms spend more than they would have without the subsidy

One caveat remains. Due to the fact that the level of the subsidy is unknown a more exact estimate of crowding out or complementary effects of public subsidies can not be made.

Table 3.9: Estimation results for absolute R&D expenditure

	Ordinary Least Squares			Sample Selection		Maximum Likelihood	
	Participants	Non-Participants	All	Participants	Non-Participants	Participants	Non-Participants
Constant	0.69 (0.43)	0.04 (0.64)	-0.18 (0.39)	0.70 (0.47)	-0.11 (0.84)	0.95 (0.57)	-0.39 (1.03)
European	-0.17 (0.30)	-0.17 (0.42)	-0.14 (0.25)	-0.17 (0.26)	-0.18 (0.38)	-0.20 (0.40)	-0.22 (0.51)
Employmt	0.62** (0.07)	0.53** (0.10)	0.61** (0.06)	0.62** (0.07)	0.54** (0.09)	0.65** (0.08)	0.56** (0.10)
Exportsh	-0.02* (0.006)	0.01 (0.009)	-0.003 (0.005)	-0.02** (0.005)	0.01 (0.008)	-0.02** (0.006)	0.01 (0.009)
Patent	0.22** (0.08)	0.26 (0.20)	0.20** (0.08)	0.22* (0.12)	0.22 (0.26)	0.13 (0.14)	0.13 (0.33)
Public	0.03 (0.28)	0.70 (0.50)	0.27 (0.27)	0.03 (0.25)	0.66 (0.46)	-0.03 (0.35)	0.63 (0.65)
Foreign	0.38 (0.30)	0.06 (0.38)	0.03 (0.24)	0.39 (0.33)	0.13 (0.43)	0.56 (0.41)	0.25 (0.52)
Quantity	-0.37 (0.25)	-0.20 (0.37)	-0.30 (0.22)	-0.37* (0.22)	-0.18 (0.34)	-0.38 (0.27)	-0.11 (0.49)
Frival	0.22 (0.24)	-0.12 (0.39)	0.12 (0.22)	0.22 (0.22)	-0.17 (0.40)	0.13 (0.26)	-0.27 (0.49)
IdeaRiv	-0.02 (0.22)	-0.21 (0.34)	-0.11 (0.22)	-0.02 (0.20)	-0.21 (0.30)	-0.04 (0.25)	-0.18 (0.41)
Dchemical	0.41 (0.30)	0.86* (0.46)	0.71** (0.28)	0.41 (0.23)	0.85** (0.41)	0.37 (0.30)	0.88 (0.57)
Detronics	0.45 (0.33)	1.85** (0.47)	1.17** (0.29)	0.45 (0.30)	1.84** (0.42)	0.47 (0.30)	1.82** (0.49)
Dequipmt	0.89** (0.42)	0.61 (0.54)	0.74** (0.35)	0.89** (0.37)	0.58 (0.49)	0.86 (0.71)	0.55 (0.51)
Denergy	0.10 (0.40)	0.83 (0.64)	0.62** (0.36)	0.11 (0.35)	0.83 (0.53)	0.13 (0.42)	0.89 (0.84)
Dservice	1.74* (0.47)	0.47 (0.55)	0.90** (0.37)	1.74** (0.42)	0.46 (0.50)	1.79** (0.47)	0.49 (0.59)
Lambdab				-0.01 (0.43)	-0.19 (0.79)		
CDTI			0.61** (0.22)				
R^2 Adjust	0.80	0.49	0.61	0.79	0.48		
Log Likel.						-265.8	
N	70	73	143	70	73	143	

*Standard errors are shown in parentheses, significance levels: ***/**/*=1/5/10%, Lambda is the inverse of the Mill's ratio, the term included to correct for selection. Its coefficient is blambda = $\sigma i \rho i$. Testing for blambda=0 is equivalent to testing for selection.*

Quelle: Busom (1999:32)

4 Conclusions

The survey on contemporary analytical firm-level studies outlined the currently available microeconometric methods of measuring leverage effects of public R&D funding. A comparison of recent company-level studies indicates the difficulties of measuring leverage effects, as the results are inconclusive: roughly half of the studies indicate complemenarity and substitution between public and private funding respectively. It has to be noted, though, that these studies employ different methods and look at different sets of data at different periods of time, and thus are not strictly comparable. In addition, especially the earlier ones use relatively simple methods. In the light of this experience, it pays to look for further methodological advances in micro-econometric evaluation techniques.

5 References

BUSOM, ISABEL [1999]: 'An Empirical Evaluation of the Effects of R&D Subsidies', Burch Center Working Paper Series B99-05, Berkeley.

CZARNITZKY, DIRK AND FIER, ANDREAS [2001]: 'Do R&D Subsidies Matter? – Evidence for the German Service Sector', Centre for European Economic Research, Working Paper Series, Mannheim.

DAVID, PAUL A. AND HALL, BRONWYN H. [2000]: 'Heart of darkness: modeling public-private funding interactions inside the R&D black box' in *Research Policy* 29, 1165-1183.

DAVID, PAUL A. ET AL. [2000]: 'Is public R&D a complement or substitute for private R&D? A review of the econometric evidence' in *Research Policy* 29, 497-529.

FÖLSTER, STEFAN [1991]: 'The Art of Encouraging Invention: A New Approach to Government Innovation Policy', The Industrial Institute for Economic and Social Research, Stockholm.

GEORGHIOU, LUKE AND ROESSNER, DAVID [2000]: 'Evaluating technology programs: tools and methods' in *Research Policy* 29, 657-678.

HALL, BRONWYN H. AND VAN REENEN, JOHN [2000]: 'How effective are fiscal incentives for R&D? A review of the evidence' in *Research Policy* 29, 449-469.

HUTSCHENREITER, GERNOT AND POLT, WOLFGANG [2001]: 'Herausforderungen für die Technologieförderung in Österreich', *Österreichs Aussenwirtschaft 2000/2001*, BMWA 03/2001:277-297

IRWIN, DOUGLAS A. AND KLENOW, PETER J. [1995]: 'High-tech R&D subsidies: Estimating the effects of Sematech' in *Journal of International Economics* 40, 323-344.

KLETTE, JAKOB ET AL. [2000] : 'Do subsidies to commercial R&D reduce market failures? Microeconometric evaluation studies' in *Research Policy* 29, 471-495.

LACH, SAUL [2000]: 'Do R&D Subsidies Stimulate or Displace Private R&D? Evidence from Israel', NBER Working Paper Series, WP 7943.

MARTIN, STEPHEN AND SCOTT, JOHN T. [2000]: 'The nature of innovation market failure and the design of public support for private innovation' in *Research Policy* 29, 437-447.

OECD [2001]: 'Public Funding of R&D: Emerging Policy Issues', Directorate for Science, Technology and Industry, Committee for Science and Technology Policy, DSTI/STP(2001)2.

WALLSTEN, SCOTT J. [2000]: 'The effects of government-industry R&D programs on private R&D: the case of the SBIR program' in *RAND Journal of Economics* Vol. 31, No. 1, Spring 2000, 82-100.

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