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Do public subsidies complement business R&D? A meta-analysis of the econometric evidence

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Abstract:

In OECD countries, governments finance around 8-10 per cent of business expenditure on R&D. Even though the existence of market failures is widely accepted as a justification for R&D public support programmes for firms it is necessary to demonstrate that these programmes are effective. Analysis of the effects of public financing on private investment in R&D has been the object of numerous applied studies without it having been possible to arrive at a definite conclusion. In this paper the results of a meta-regression of econometric evidence on the relationship between public funding of R&D and private R&D expenditures is presented. After the creation of a data-base including all relevant studies and their results and characteristics, a meta-analysis was carried out to examine whether the characteristics of the applied analysis influence the results and explain the differences in the empirical literature on this subject.

Keywords: meta-analysis, R&D, technology policy
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DO PUBLIC SUBSIDIES COMPLEMENT BUSINESS R&D?
A META-ANALYSIS OF THE ECONOMETRIC EVIDENCE

I. INTRODUCTION[1]

In OECD countries, governments finance around 8-10 per cent of business expenditure on R&D. In contrast to the reservations held about public support to enterprise in the areas of investment, production, or commercial protection, government support to the R&D activities of private enterprise are accepted among national and international competitors. The broad consensus on the worth of public support to R&D is based upon the existence of market failures (Arrow, 1962) that create a gap between the private and the social benefits derived from R&D activities, and this gap means that private resources dedicated to R&D activities will always be below the social optimum (Klette et al., 2000).

The market failures that imply investment in R&D below the optimum level are derived from the incomplete appropriability of the results of the research (Arrow, 1962). This is due, to a certain extent, to its nature as a public good, to the type of knowledge generated, and to the appearance of external economies in the form of spillovers. From this incomplete appropriability arises the recommendation that public subsidies and other action in technology policy be used to increase the proportion of resources assigned to R&D activities as well as to promote the innovation activities of firms.

Nevertheless, even though the existence market failures is widely accepted as a justification for public support programmes for firms it is necessary to demonstrate that these programmes are effective. To do this it must be shown that the principle of additionality is fulfilled. This principle demands that public subsidies to firms really are transformed into an increase in their research and innovation effort, and that they do not merely substitute private expenditure that would have been made in any case. Although this condition apparently presents few difficulties of evaluation, it is in fact not easy to achieve clear results. The question of whether public support complements or substitutes private R&D is a fundamental matter in the design of technology policy.

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From a theoretical point of view, arguments exist to support both hypotheses. The existence of support for R&D could constitute a stimulus to firms to begin R&D or increase their resources assigned to R&D, as it reduces marginal costs and increases the profitability of R&D projects. On the other hand, public support for R&D could reduce the private effort in R&D, as the firms could substitute their own financing with public funding on projects that they would have carried out in any case.

Analysis of the effects of public financing on private investment in R&D has been the object of numerous applied studies without it having been possible for any of them to arrive at a definite conclusions (Capron, 1992, Capron and Van Pottelsberghe, 1997, David et al. 2000). Particularly, an excellent recent review (David et al., 2000) of the econometric evidence on the relationship between public funding of R&D and private R&D expenditure shows the difficulty to be found in arriving to any empirical conclusion regarding the sign and the magnitude of this relationship. Nevertheless, as the authors state, "the econometric results… tend to be running in favour of findings of complementarity between public and private R&D investments but that reading is simply an un-weighted summary based upon some 30 diverse studies: it is not a conclusion derived from a formal statistical meta-analysis". Although David et al. (2000) point to the limitations and the difficulties there are in carrying out a meta-analysis, as Stanley (2001) states, "meta-regression analysis can identify the extent to which the particular choice of method, designs and data affect reported results". This is of particular interest because as Capron and Van Pottelsbergue (1997) point out, after a review of the empirical literature on this subject, "it seems that empirical specification may…influence the sign of the parameter of interest".

The use of quantitative techniques -meta-analysis- has been gaining importance in recent years as a means of reviewing literature and synthesising existing results (Hunt, 1997; Stanley, 2001; Florax et al., 2002). In this paper the results of a meta-regression on econometric evidence concerning the relationship between public funding of R&D and private R&D expenditure is presented. The rest of the paper is organised as follows. In the next section the meta-regression is carried out following the usual steps in this kind of approach and the main subjects of interest in the econometric evidence are presented. Afterwards, the main conclusions are presented and some recommendations for future research made.

II. META-REGRESSION OF THE ECONOMETRIC EVIDENCE

The first step in carrying out a meta-analysis (Stanley, 2001, Florax et al., 2002) is to create a data-base that includes all the relevant studies, their characteristics and their results. In this case the construction of the data-base started by including all the studies presented in the existing reviews of the econometric evidence (Capron, 1992; Capron and Van Pottelsberghe, 1997; Van Pottelsberghe, 1997; David et al. 2000). This was complemented with a computer search with the use of EconLit. In the end, 39 empirical studies were used in the meta-analysis[2]. As is usual, most of these studies present more than one result. Due to the fact that the various results correspond to estimations for different sectors or countries, all of them have been included in the meta-regression. This means 74 different results on the relationship between public funding of R&D and privately financed R&D expenditures. The main characteristics of these studies and their findings are presented in the annex.

In this case, the objective of the meta-regression is to explain the variation in either the sign or the magnitude between public funding of R&D and private R&D expenditure. Formally, the empirical studies estimate the following equation:

$$BGID_i = f\,(PGID_i, Z_i) \qquad (1)$$

in which $BGID_i$ is private expenditure on R&D financed by the firms themselves, i is firms, sectors or countries, $PGID_i$ is public financing of private R&D and Z_i the vector of the other variables that influence effort by firms, sectors or countries in R&D. The possible results of these estimations are that the estimated coefficient associated with public R&D is positive and significant, which would indicate an additional effect, whereas on private R&D it could be negative and significant, showing a substitution effect, or it could be not significant, which would mean that public subsidies do not provide an incentive for new private expenditure on R&D but neither have a crowding-out effect.

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[2] Meta-analyses are confronted with the problem of editorial bias. For example, editors may be more inclined to reject studies with results that are not significant. (Stanley, 2001). In this case, this problem is smaller because, as is shown later, with any of the three possible results that are obtained with the applied analyses relevant conclusions are derived about the effects of public subsidies on R&D. In addition, as far as is possible, unpublished papers have been included.

To compare the results of the existing studies it is necessary to have a summary statistic, which is the dependent variable in the meta-regression. This is not an easy task and it is a common problem in meta-analysis. The empirical studies used in this meta-analysis sometimes estimate elasticities and other marginal effects without it being possible, in most of them, to calculate dimension-free parameter estimates such as elasticities due to the absence of necessary statistical information. Also some studies define the dependent variable as total R&D expenditures without subtracting R&D subsidies, and then the estimated coefficient has to be interpreted in a different way. Furthermore, the researchers in this field are more interested in the significance of the coefficient and in its sign than in magnitude because of the limitations and the difficulties in estimating magnitude properly. Therefore the same approach is followed here as is common in medicine and psychology meta-analyses which attempt to analyse the effects of treatment defining a binary outcome (1 = improved, 0 = not improved)[3], considering:

YC = 1 if there is an additional effect of public funding of R&D on private R&D
YC = 0 in the other cases, with an insignificant or a crowding-out effect.

Because the worst effect of technology policy would be to create a crowding-out effect, as a complementary method some estimations have been carried out defining the dependent variable (YS) as 1 = crowding-out effect, 0 = in the other cases. The purpose of this is to try to identify the extent to which a particular method, design and data may lead to this result[4].

The objective of a meta-analysis is to examine whether the characteristics of studies influence the results. These characteristics are the independent variables –also frequently called moderator variables- in the meta-regression. The variables are presented in Table 1.

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3 Binary models have also been used in meta-analysis in economics. See, for example Florax et al. (2001) and Nijkamp and Poot (2002)

4 Another possibility is to define three categories and use a multinomial model. However, when this procedure was also used the results led to the same conclusions. In addition, the distinction between the case of complementarity, the objective pursued by technology policy, and the rest of the possibilities, is more interesting.

Table 1. Meta-independent variables

OBS = Number of observations
YPAP = Year of the paper
NAUT = Number of authors
FIRM = 1 if a firm-level study
IND = 1 if an industry-level study
US = 1 if a study using U.S data
TIME = 1 if the average year of the data is from 1980 to the present
STRUCTURE = 1 if a study uses panel data
RPL = 1 if a study uses a lagged dependent variable
Q = 1 if a study uses sales as an independent variable
C4 = 1 if a study uses a concentration index as an independent variable
IFDUM = 1 if a study uses firm or industry dummies
TDUM = 1 if a study uses time dummies

Apart from the independent variables corresponding to some estimation characteristics such as the use of dummies, or some common moderator variables such as the number of observations or the year of the paper, four subjects are particularly interesting in the empirical analysis of the effects of public R&D subsidies. These subjects are:

a) The level of analysis. The existing studies have used three levels of analysis: firm-level studies (or even below that level, for example specific line of business and laboratory level studies), industry-level studies and aggregate studies (with country data). None of them are problem-free. Firm-level studies are preferable from a theoretical point of view because the firm is the real agent and so it is easier to model its behaviour. Nevertheless firm-level studies have the problem of lack of data and particularly the assumption that the level of government support is an exogenous variable, which is rather questionable or even, for some authors, almost unacceptable (Kauko, 1996). As Lichetenberg (1984) states: "Federal contracts do not descend upon firms like manna from heaven". Public funding should be considered an endogenous variable because a firm, in order to receive public funding, must apply for it and the public agency may or may not award it, depending on the firm's and project's characteristics (Busom, 2000) and there is therefore a problem of simultaneity and selection bias in the funding process that affects the econometric analysis (David et al., 2000). For the other levels of study, industry-level and with country data, the exogeneity assumption is much more acceptable (Capron and Van Pottelsberghe, 1997) although these empirical analyses are not problem-free either. The analysis at the industry-level may be affected by sectoral differences in technological opportunity. A result of complementarity between public funding and private R&D expenditure may be explained, if appropriate controls have not been used, by the fact that some industries have greater technological opportunities than others. At the aggregate level, as David et al. (2000) point out, there are also difficulties in the estimation because the effect of government funding on input R&D prices may contribute to the existence of complementarity between public and private R&D.

A simple vote-counting of the existing results is presented in Table 2. The results seem to show a greater presence of substitutability when the level of analysis is firm data. Nevertheless, the vote-counting is presented with the sole object of illustrating the existing evidence. The use of vote-counting frequently leads to an incorrect conclusion and shows bias in favour of finding insignificant effects (Stanley, 2001; Florax et al., 2002).

Table 2. Summary of the distribution of the econometric evidence (according to the level of analysis*)

	Complementarity	Insignificant	Substitutability	Total
Firm	17	10	11	38
Industry	8	3	1	12
Country	13	6	5	24
Total	38	19	17	74

(*) Number of studies reporting complementarity, insignificant or substitution effects at the different levels of analysis.

b) The country of analysis. Technology policy has different characteristics in the advanced countries that may influence public subsidies for the private financing of R&D activities. A simple vote-counting of the existing results is shown in Table 3, distinguishing between the USA and other countries. In the same way as in other reviews of the literature (David et al., 2000), the existence of complementarity in the case of the United States is slightly less frequent than in the other countries, although without the differences being statistically significant. Nevertheless vote-counting can lead, as has been pointed out, to erroneous conclusions, for which reason the inclusion of this variable in the meta-regression should allow a more precise examination of whether significant differences exist in the effects of public subsidies for R&D in relation to the country of analysis.

Table 3. Summary of the distribution of the econometric evidence*

	Complementarity	Insignificant	Substitutability	Total
Based on US data	22	13	10	45
Based on other countries data	16	6	7	29
Total	38	19	17	74

(*) Number of studies reporting complementarity, insignificant or substitution effects in the US or other countries

c) Structure of the data. Existing analyses have used various types of data. More precisely, the use of cross-section, time series and panel data can be distinguished. Although the suitability of one or the other depends on the purpose of the analysis, for the study of the effects of public support for R&D the use of panel data is the preferable option given the need to control the heterogeneity of the firms, sectors or countries, to analyse the dynamic process and measure very precisely some effects that are difficult to detect using cross-section or time series data, among other reasons. As Baltagi (1995) points out, panel data has, among other advantages, the capacity to control individual heterogeneity, the possibility of enjoying a greater degree of freedom, greater variability and less colinearity between its variables, the ability to identify and measure effects that cross-section and time series data do not detect and the possibility of constructing and examining more complicated behavioural models than purely cross-section or time series data. Therefore the inclusion in the meta-analysis of an independent variable that brings in the type of structure used allows the question of whether the use of panel data more frequently leads to a definite result in relation to the effects of public subsidies for R&D on private financing of research activities to be examined.

d) The dynamic feature of the model. As Capron and Van Pottelsbergue (1997) point out: “introducing a dynamic feature in the empirical model may modify substantially the sign and the significance of the estimated relationship between government and private R&D". Of the 39 articles analysed only 12 introduce a lagged private R&D variable. Nevertheless, expenditure in previous periods has a strong influence on the present level of resources that firms allocate to R&D (Mansfield, 1964; Hamberg, 1966; Capron and Van Pottelsbergue, 1997, Guellec and Van Pottelsbergue, 2001). Because of this it is convenient to analyse in the meta-regression the question of whether the use of dynamic models implies variations in the results regarding the influence of public financing of R&D on the private financing.

Finally it should be underlined that the studies carried out have a high degree of heterogeneity[5] with significant differences with regard to the periods analysed or the sources of information, besides those mentioned previously. In addition, the number of independent variables used in the empirical analysis is widely varied and goes from using only the public financing of R&D as an explaining variable to the use of eight independent variables, as in the case of Switzer (1984).

The results are shown in Table 4. Given the binary nature of the dependent variable the estimation has been carried out with a logit model. In the first column the estimation including practically all the independent variables is shown. The results show that none of these is significant which allows the conclusion to be drawn that there are no characteristics of applied studies that lead with greater frequency to a result of complementarity between the public financing and the private financing of R&D. The use of the lowest number of independent variables to analyse the characteristics regarding the level of the analysis, the country and the structure of the data lead to the same conclusion and none of the variables is significant. The same estimation has been

[5] Heterogeneity is a common problem in meta-analyses in economics. As Florax et al. (2002) point out: "In medicine and the sciences replication is a common characteristic. In economics on the contrary, it seems to be a common desideratum to be original and innovative". Nevertheless, the narrative and the vote-counting literature reviews are confronted with the same problem.

carried out using the alternative proposed previously as a dependent variable (YS), in which it is defined as 1 = crowding-out effect, 0 = in the other cases. The results provide weak evidence that the analyses carried out with data from firms lead to the existence of a crowding-out effect between the public and private financing of R&D while the rest of the variables are not significant[6].

Table 4. Results of the meta-regression

	(1)	(2)	(3)
	YC	YC	YS
C	-0.0475 (-0.054)	0.514 (0.737)	-1.969 (-2.144)
FIRM	-0.607 (-0.673)	-0.788 (-1.199)	1.445 (1.676)*
IND	0.050 (0.051)		
US	-0.003 (-0.004)	-0.117 (-0.181)	-0.439 (-0.547)
TIME	-0.618 (-0.747)	-0.055 (-0.085)	-0.495 (-0.610)
STRUCTURE	-0.040 (-0.053)	-0.265 (-0.398)	0.893 (1.032)
OBSV	0.001 (0.807)	0.001 (1.072)	-0.000 (-0.203)
RPL	-0.448 (-0.693)		
Q	0.346 (0.486)		
C4	-0.741 (-0.889)		
IFDUM	1.127 (1.512)		
TDUM	0.596 (1.512)		
N	74	74	74
Obs with Dep = 1	38	38	17
Log likelihood	-46.184	-49.859	-38.213
Restr. log likelihood	-51.266	-51.266	-39.882
LR statistic	10.164	2.813	3.339
McFadden R-squared	0.099	0.027	0.042

z-statistics between parentheses. * statistically significant at a 10 per cent probability threshold.

6 For both dependent variables various estimations with different alternatives of the independent variables were carried out without obtaining any change in the results shown. A probit model also yielded similar results.

III. CONCLUSIONS

The econometric evidence on the relation between public funding of business R&D and private R&D expenditure is ambiguous. The literature on this relationship is fundamentally of an empirical and descriptive nature obtaining contradictory results that are difficult to reconcile.

In this paper a meta-analysis has been carried out to synthesise previously obtained research results on this subject. Although meta-analysis is not free from problems it is a useful alternative in attempting to determine whether a particular choice of method, design and data affect reported results (Stanley, 2001). The results show that there are no specific study characteristics that lead to a particular result - complementary or substitution effect between public funds and private financing of R&D-. There is only very weak evidence that with the use of firm data, the crowding-out effect is more frequent. This result reinforces and complements the conclusions obtained in the reviews of the literature and shows that it is not possible to obtain any regularity in the relation between the principal characteristics of the design of applied analyses and the results obtained by them.

To advance in this field of research and to arrive at conclusions that are of use in the design of technology policy it seems necessary, as David et al. (2000) point out, to make an effort in structural modelisation that would allow the channels of repercussion of public funding of R&D on business behaviour to be identified. It is also necessary, as recent analyses do (Busom, 2000), to include the factors that determine governmental decisions with regard to the concession or not of public funding.

Advances in the economic analysis of the evaluation of technology policy are confronted with a scarcity of information and the difficulty of establishing control groups precisely, distinguishing between the firms that receive subsidies and those that do not. Therefore it is necessary that the evaluation forms an integral part of the design of technology policy and the concession of subsidies, common methodologies being agreed upon in the various countries, in the same way as is done for the definition and collection of R&D and innovation indicators (Heijs, 2001). This would facilitate the availability of more information and the use, together with the econometric approaches examined in this meta-analysis, of alternative research methods such as quasi-experimental methods (David et al., 2000). All of this should allow progress to be made on the comparison of the results, and in determining whether a complementarity or a substitution effect predominates between public support for R&D and private funding, and consequently to have more precise knowledge about the effects of technology policy that still seems to be today, as Rothwell and Zegveld (1988) point out, more a matter of faith than of understanding .

Appendix. Summary of the existing studies

AUTHOR	TIME PERIOD	STRUCT (1)	LEVEL (2)	COUNTRY		SAMPLE	NET FIND. (3)
Hamberg (1966)	1960	C.S	F	USA	Aircraft	20	I
					Chemicals	34	C
					Electronic components	24	C
					Other electr. Equipment	27	C
					Office machines	12	C
					Instruments	18	I
					Rubber products	16	I
					Transport equipment	18	I
Globerman (1973)	1965-69	C.S	I	CANADA		15	C
Buxton (1975)	1965	C.S	I	UK		11	C
Howe and Mc. Fetridge (1976)	1967-71	C.S	F	CANADA		264	C
Rosenberg (1976)	1963	C.S	F	USA		100	C
Shrieves (1978)	1965	C.S	F	USA	Manufactur.	411	S
					Non-specialized durables	49	I
					Materials	148	C
					Specialized durable equipment	128	S
					Consumer goods	82	I
Goldberg (1979)	1958-75	T.S.C.S	I	USA		252	C
Nadiri (1980)	1969-75	T.S.C.S	I	USA	Manufactur.	70	C
					Durables	35	S
					Non durables	35	C
Carmichael (1981)	1976-77	C.S	F	USA	Transport firms	92	S
					Big transport firms	46	I
					Small transport firms	46	S
Higgins and Link (1981)	1977	C.S	F	USA		174	S
Link (1982)	1977	C.S	F	USA		275	C
Levy and Terleckyj (1983)	1949-81	T.S	C	USA		33	C
Gannicot (1984)	1976-77	C.S	I	AUSTRALIA		22	I
Levin and Reiss (1984)	1963, 1967, 1972	T.S.C.S	I	USA		60	C
Lichtenberg (1984)	1972	C.S	F	USA		991	C
	1977	C.S	F	USA		991	S
	1972-77	C.S	F	USA		991	S
	1967-77	C.S	F	USA		991	S
	1963-79	T.S.C.S	I	USA		204	I
Scott (1984)	1974	C.S	F	USA		3387	C

Appendix. Summary of the existing studies (continuation)

AUTHOR	TIME PERIOD	STRUCT (1)	LEVEL (2)	COUNTRY	SAMPLE	NET FIND. (3)
Switzer (1984)	1977	C.S	F	USA	125	I
Lafuente et al. (1985)	1980	C.S	I	SPAIN	26	I
Terleckyj (1985)	1964-84	T.S	C	USA	21	C
Lichtenberg (1987)	1979-84	T.S.C.S	F	USA	187	C
				USA	1122	I
	1956-83	T.S	C	USA	28	C
				USA	28	I
Holemans and Sleuwaegen (1988)	1980-84	T.S.C.S	F	BELGIUM	236	C
Antonelli (1989)	1983	C.S	F	ITALY	86	C
Leyden et al. (1989)	1987	C.S	F	USA	120	I
Levy (1990)	1963-84	T.S.C.S	C	USA	189	C
				UK	189	S
				ITALY	189	I
				JAPAN	189	C
				GERMANY	189	C
				SWEDEN	189	C
				NETHERLAND	189	S
				FRANCE	189	C
				SWITZERLAND	189	I
Leyden and Link (1991)	1987	C.S	F	USA	137	C
Robson (1993)	1955-88	T.S	C	USA	33	C
Crott (1995)	1984-87	T.S.C.S	F	BELGIUM	30	C
Fölster and Trofimov (1996)	1982-90	T.S.C.S	F	SWEDEN	249	S
Mamuneas and Nadiri (1996)	1956-88	T.S.C.S	I	USA	495	C
Capron and Van Pottelsbergue (1997)	1974-90	T.S.C.S	C	USA	119	I
				CANADA	119	S
				GERMANY	119	I
				FRANCE	119	S
				ITALY	119	S
				JAPAN	119	I
				UK	119	C
Diamond (1998)	1953-93	T.S	C	USA	41	C
Klette and Moen (1998)	1982-95	T.S.C.S	F	NORWAY	2688	C
Toivanen and Niininen (1998)	1989,91,1993	T.S.C.S	F	FINLAND	399	S
Von Tunzelmann and Martin (1998)	1969-95	T.S.C.S	C	22 OECD Countries	594	C
Wallsten (1999)	1990-92	C.S	F	USA	81	S
Busom (2000)	1988	C.S	F	SPAIN	147	C
Guellec and Van Pottelsberghe (2001)	1981-96	T.S.C.S	C	17 OECD Countries	216	C
Callejon and Garcia Quevedo (2002)	1989-98	T.S.C.S	I	SPAIN	264	C

(1) STRUCT: data structure. C.S: cross-section; T.S: time-series; T.S.C.S: panel data
(2) LEVEL. F: firm; I: industry; C: country.
(3) NET FINDINGS: C: complementarity; I: insignificant; S: substitutability.
Source: Capron (1992), Capron and Van Pottelsbergue (1997), David et al. (2000) and complied by the author.

References

Arrow, K. (1962): “Economic welfare and the allocation of resources for inventions” en R. Nelson (ed.): *The rate and direction of inventive activity,* Princenton University Press.

Baltagi, B. (1995): *Econometric analysis of panel data*, John Wiley & Sons Ltd., England.

Busom, I. (2000): “An empirical evaluation of R&D subsidies”, *Economics of innovation and new technology*, vol. 9, 2, pp. 111-148.

Capron, H. (1992): *Economic quantitative methods for the evaluation of the impact of R+D programmes*, EUR 14864 EN, European Commission, Brussels.

Capron, H., Van Pottelsbergue, B. (1997): “Public support to business R&D: a survey and some new quantitative evidence” in OECD: *Policy evaluation in innovation and technology. Towards best practices*, Paris.

David, P., Hall, B. and Toole, A. (2000): “Is public R&D a complement or substitute for private R&D? A review of the econometric evidence, *Research Policy*, 29, pp. 497-529.

Florax, R.; Lopez-Bazo, E., Lopez-Tamayo, J.; Waldorf, B. (2001): “The Labor market matching function. A quantitative assessment of theoretical, methodological and empirical issues”, Paper presented at IV Encuentro de Economía Aplicada, Reus (Spain).

Florax, R., de Groot, H. and de Mooij, R. (2002): *Meta-analysis: a tool for upgrading inputs of macroeconomic policy models*, Tinbergen Institute Discussion Paper TI 2002-041/3.

Hamberg, D. (1966): *Essays on the Economics of Research and Development*, Random House, New York.

Heijs, J. (2001): *Evaluación de la financiación pública de I+D en España*, Colección estudios 117, Consejo Económico y Social, Madrid.

Hunt, M. (1997): *How science takes stock: the story of meta-analysis*, New York, Rusell Stage Foundation.

Kauko, K. (1996), “Effectiveness of R&D subsidies – a sceptical note on the empirical literature”, *Research Policy* 25, pp. 321-323.

Klette, J., Moen, J. and Griliches, Z. (2000): “Do subsidies to commercial R&D reduce market failures?. Microeconomic evaluation studies, *Research Policy*, 29, pp. 471-495.

Lichtenberg, F. (1984): “The relationship between federal contract R&D and company R&D”, *American Economic Review Papers and Proceedings* 74, pp 73-78.

Mansfield, E. (1964): "Rates of return from industrial and research development", *American Economic Review* 55, pp. 310-322.

Nijkamp, P., Poot, J. (2002): *Meta-analysis of the impact of fiscal policies on long-run growth*, Tinbergen Institute Discussion Paper TI 2002-028/3.

Stanley, T.D. (2001): "Wheat from chaff: Meta-analysis as quantitative literature review", *Journal of Economic Perspectives* 15 (3), pp. 131-150.

Switzer, L. (1984): "The determinants of industrial R&D: a funds flow simultaneous equation approach", *The Review of Economics and Statistics* 66 (1), pp. 163-166.

Rothwell, R. and Zegveld, W. (1988): “An assessment of Government innovation policy” in Roessner, J. (ed.), *Government innovation policy: design, implementation, evaluation,* St Martin’s, New York.

References of the meta-analysis:

Antonelli, C. (1989): "A failure-inducement model of research and development expenditures", *Journal of Economic Behaviour and Organization*, 12, pp.159-180.

Busom, I. (2000): "An empirical evaluation of R&D subsidies", *Economics of innovation and new technology*, vol. 9, 2, pp. 111-148.

Buxton, A. (1975): "The process of technical change in UK manufacturing", *Applied Economics* 7, pp. 53-71.

Callejón, M., García Quevedo, J. (2002): *Las ayudas públicas a la I+D empresarial. Un análisis sectorial*. Working Paper 2002/6, Instituto de Economía de Barcelona, University of Barcelona.

Capron, H., Van Pottelsbergue, B. (1997): "Public support to business R&D: a survey and some new quantitative evidence" in OECD: *Policy evaluation in innovation and technology. Towards best practices*, Paris

Carmichael, J. (1981): "The effect of mission-oriented public R&D spending on private industry", *Journal of Finance* 36, pp. 617-627.

Crott, R. (1995): *Evaluation de l'impact des aides publiques directes à la recherche industrielle: une étude empirique sur enterprises wallonnes et belges*, PhD Thesis, Universithé Catholique de Louvain, Nouvelle série 246.

Diamond, A.M. (1998): "Does federal funding crowd out private funding of science?", Presentation at the American Economics Association meetings, Chicago, January.

Folster, S., Trofimov, G. (1996): "Do subsidies to R&D actually stimulate R&D investment?", mimeo, The Industrial Institute of Economic and Social Research.

Gannicot, K. (1984). "The determinants of industrial R&D in Australia", *Economic Record* 60, pp. 231-235.

Globerman, S. (1973): "Market structure and R&D in Canadian manufacturing industries", *Quarterly Review of Economics and Business* 13, pp. 59-68.

Goldberg, L. (1979): *The influence of federal R&D funding on the demand for and returns to industrial R&D*, Working Paper CRC-388. The Public Research Institute.

Guellec, D., Van Pottelsbergue, B. (2001): "The effectiveness of public policies in R&D", *Revue d'Economie Industrielle* 94, pp. 49-68.

Hamberg, D. (1966): *Essays on the Economics of Research and Development*, Random House, New York.

Higgins, R., Link, A. (1981): "Federal support on technology growth in industry: some evidence of crowding-out", *IEEE Transactions on Engineering Management* EM-28, pp. 86-88.

Holemans, B., Sleuwaegen, L. (1988): "Innovation expenditures and the role of government in Belgium", *Research Policy* 17, pp. 375-379.

Howe, J., McFetridge, D. (1976): "The determinants of R&D expenditure", *Canadian Journal of Economics* 9, pp. 57-71.

Klette, T., Moen, J. (1998): "R&D investments responses to R&D subsidies: a theoretical analysis and econometric evidence". Presentation at the NBER Summer Institute, July.

Lafuente, A,. Salas, V. and Yagüe, M. (1985): "Formación de capital tecnológico en la industria española", *Revista Española de Economía* nº 2

Levin, R., Reiss, P. (1984): “Test of a Schumpeterian model of R&D and market structure” in Z. Griliches (ed.): *R&D, Patents and Productivity*, National Bureau of Economic Research, The University of Chicago Press.

Levy, D. (1990): "Estimating the impact of government R&D", *Economic Letters* 32 (2), pp. 169-173.

Levy, D., Terleckyj, N. (1983): "Effects of government R&D on private R&D investment and productivity: a macroeconomic analysis", *Bell Journal of Economics* 14, pp. 551-561.

Leyden, D., Link, A. (1987): "Why are governmental R&D and private R&D complements?", *Applied Economics* 23 (10), pp. 173-81.

Leyden, D., Link, A., and Bozeman, B. (1989): "The effects of governmental financing on firms' R&D activities: a theoretical and empirical investigation", *Technovation* 9, 561-575.

Lichtenberg, F. (1984): “The relationship between federal contract R&D and company R&D”, *American Economic Review Papers and Proceedings* 74, pp 73-78.

Lichtenberg, F. (1987): “ The effect of government funding on private industrial research and development: a re-assesment”, *The Journal of Industrial Economics* Vol. XXXVI, 1, pp. 97-104.

Link, A. (1982): "An analysis of the composition of R&D spending", *Southern Economic Journal* 49 (2), pp. 342-349.

Mamuneas, T., Nadiri, M. (1996): “Public R&D policies and cost behaviour of the US manufacturing industries”, *Journal of Public Economics* 63, pp. 57-81.

Nadiri, M. (1980): “Contributions and determinants of research and development expenditures in the US manufacturing industries” en G. Von Furstenberg (Ed.): *Capital, efficiency and growth*, Ballinger Publishing Company, Cambridge.

Robson, M. (1993): "Federal funding and the level of private expenditures on basic research", *Southern Economic Journal* 60, pp. 63-71.

Rosenberg, N. (1976): "Research and market shares: a reappraisal of the Schumpeter hypothesis", *The Journal of Industrial Economics* 25 (2), pp. 101-112.

Scott, J. (1984): "Firm versus industry variability in R&D intensity" in Griliches, Z. (Ed.): *R&D, patents and productivity*; University of Chicago Press, Chicago.

Schrieves, R. (1978): "Market structure and innovation: a new perspective", *The Journal of Industrial Economics* 26 (4), pp. 329-347.

Switzer, L. (1984): "The determinants of industrial R&D: a funds flow simultaneous equation approach", *The Review of Economics and Statistics* 66 (1), pp. 163-166.

Terleckyj, N. (1985): "Measuring economic effects of federal research and development expenditures, recent history with special emphasis on federal R&D performed in industry", Paper prepared for the Workshop on the Federal role in Research and Development, National Academics of Science and Engineering, Washington, DC.

Toivanen, O., Niininen, P. (1998): *Investment, R&D subsidies and credit constraint*, Working Paper, Department of Economics MIT and Helsinki School of Economics.

Von Tunzelmann, N., Martin, B. (1998): *Public vs. Private funding of R&D and rates of growth: 1963-1995*, Working Paper, Science Policy Research Unit (SPRU), University of Sussex.

Wallsten, S. (1999): *Do government-industry R&D programs increase private R&D?. The case of the Small Business Innovation Research Program*, Working Paper, Department of Economics, Stanford University.