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Return to business R&D expenditures in the Netherlands

Keywords: Research and development, returns measurement, economic growth, model estimation

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Return to business R&D expenditures in the Netherlands

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Abstract:
The main goal of the study is to evaluate the rate of return to R&D expenditures carried out by private enterprise in the Netherlands based on sectoral and microeconomic datasets. We have applied the production function approach common in the literature to econometrically estimate the rate of return and differentiate the rate of return between government and private financing of R&D expenditures at the firm level. Another goal was to examine the multiplier effect of government R&D financing. The study concluded that one euro spent on R&D returned, on average, at least 2.3 euro over the lifetime of investment, including 1.6 euro in the sector where the R&D was carried out and an extra 0.7 euro via the purchasing of investment goods (machinery and software), with time lags of one to two years before the first positive annual return to the investment. Return to privately-financed R&D are higher than to government-financed. There is a multiplier effect of the public financing on private expenditures, with the elasticity between 0.05 and 0.1.

JEL codes: O41, O33, O47

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1 Introduction

The main goal of the study is to evaluate the rate of return to R&D expenditures carried out by private enterprise in the Netherlands based on sectoral statistics over the last 20-plus years and microeconomic datasets over the last 10 years.

The state-of-art in evaluating rates of return to R&D expenditures features multiple studies based on data for OECD as a whole as well as some individual countries. While macro datasets are used for the OECD-based studies, the more specific estimates are based on micro data sets for different countries/sectors. The returns to R&D expenditures vary wildly over country, sector and time period. The survey articles put the most prevalent rates of return at about 20-30 per cent for the first year when the benefit occurs (see Hall et al. 2010 and Mairesse and Mohen 2010 for overviews of literature). However, no reliable estimates for the Netherlands exist so far. CPB assumes R&D expenditures are cost without benefits in the sort-term (up to two years) in the macroeconomic model. In order to fill this gap, this study applies econometric methods to estimate the rates of return to R&D expenditures in the Netherlands over the last 22 years and 25 sectors, which account for almost all BERD.

Another goal was to examine the multiplier effect of government R&D financing, that is, to what extent extra private investment in R&D is generated or supressed by government financing. The literature generally suggests a multiplier effect (complementarity) of government R&D financing, albeit with some evidence to the contrary for some countries and time periods. The literature generally suggests a multiplier effect (complementarity) on private R&D expenditure by R&D financing: that is, the multiplier coefficient is larger than one. However, for some countries and time periods there is evidence to the contrary (multiplier is less than one). David *et al.* argued that the econometric results available in the literature tend to be in favour of complementarity between public and private R&D investments. González *et al*. (2006) suggest that government financing stimulate private R&D activities, with no crowding out of private expenditures. On the contrary, Wallsten (2000) concludes based on the SBIR programme that the public grants crowd out firm-financed R&D expenditures dollar for dollar.

The remainder of the paper is distributed as follows. Section 2 presents the methodological approach and mathematical formulations followed by a description of the data. Section 3 presents the results of the estimation without intersectoral spillovers, whereas the results in the subsequent chapter does include intersectoral spillovers. Section 5 is about the dependence of economic growth on R&D stock and chapter 6 presents an analysis using micro datasets for the estimation of returns to R&D and impact of government financing on business R&D expenditures. Chapter 7 presents evidence on the question of what extent extra private investment in R&D is generated or suppressed by government R&D financing followed by a the estimation of output elasticity with respect to the change in R&D stock. The final chapter presents the conclusions of this work.

2 Approach and data

R&D expenditures are classified in statistics in accordance with two criteria: by financing and by implementation:

Table 1. Scope of study.

Implementation Financing	Public (government research and research in universities)	Business (research by private firms)
Private		assessed
Government		assessed
Other		assessed

We considered R&D expenditures carried out by business (BERD) and financed with both public and private funds. The analysis of publicly-executed research requires more data than were available for this study.

Most of the studies measuring returns to R&D investments as based on production function approach. We also take the production function approach in its primal form, as referred to in Hall et. Al. (2010), where the production function is being estimated with quantities as inputs. In order to derive the formula for the rate of return to R&D expenditure, we start with a stylized Cobb-Douglas production function:

$$Y = A \cdot L^{\alpha} \cdot K^{\beta} \cdot RDC^{\gamma 1} \cdot RDCS^{\gamma 2} \cdot e^{u} \qquad (0.1)$$

where *Y* is the measure of production level, *A* is the level of technical progress, *L* is the labour input, *K* is the input of ordinary capital, *RDC* is own R&D capital, *RDCS* is external R&D capital and *u* is a disturbance. Since the left-hand side of the production function does not include intermediate inputs, we are taking value added at the measure of production level. The Cobb-Douglas production function can be linearized by taking logs of both sides of the equation.

$$y = a + \alpha l + \beta k + \gamma_1 rdc + \gamma_2 rdcs + u \qquad (0.2)$$

When dealing with time-series data we can take the first differences of the equation in order to arrive to growth rates:

$$\Delta y_t = a_t + \alpha \Delta l_t + \beta \Delta k_t + \gamma_1 \Delta rdc_t + \gamma_2 \Delta rdcs_t + \Delta u_t \qquad (0.3)$$

Where a_t is effectively a time dummy.

If we redefine $\gamma_1 = \rho_1 \frac{RDC}{Y}$ and $\gamma_2 = \rho_2 \frac{RDCS}{Y}$, we get our main specification written as:

$$\Delta y_t = a_t + \alpha \Delta l_t + \beta \Delta k_t + \rho_1 \frac{\Delta RDC_t}{Y_t} + \rho_2 \frac{\Delta RDCS_t}{Y_t} + \Delta u_t \qquad (0.4)$$

Taking into account that $\Delta y_t \approx \frac{\Delta Y_t}{Y_t}$, ρ shows the increase in value added per unit (one euro) increase in R&D capital. This means that by using the formulation (0.4) we can estimate the return to R&D investments directly.

Equation (0.4) links increase in the level of production with the changes in R&D expenditures *ceteris paribus*. Hence it shows how the production can be increased while keeping labour and ordinary capital inputs constant. This gives another interpretation of the equation: effects of increase in R&D capital on Total Factor Productivity.

The dataset used for macroeconomic analysis is based on the data from Statline of CBS of the Netherlands and partly from OECD. The key variables needed for the regression analysis include value added, labour, ordinary capital and R&D expenditure. The sector and time scope of these variables differ, with R&D expenditures being the less detailed and the shortest time series. CBS time series of R&D expenditures starts from 1994, for some sectors the series are extended back to 1988 based on OECD data. Taking into account this limitation, our final macro-dataset runs from 1988 to 2010 and includes 25 sectors: agriculture, mining, 16 industry sectors and 7 types of services.

In order to estimate equation (0.4), we need to convert the variables to the real growth rate terms. Some of the variables are already available in CBS in the physical volume: value added in the 2005 constant prices, labour in worked hours and ordinary capital in the form of volume-indices (2005=100). The R&D expenditure data are available in the form of the business enterprise expenditure on research and development in current prices.

We have converted these series into constant prices using three alternative prices deflators: the GDP deflator, the research sector[1] value added deflator and the R&D sector wage deflator (that is, the deflator equals the change in wages). Data on R&D capital is not collected by statistical offices and therefore needs to be estimated based on the time series of R&D expenditures via the standard approach to stock estimation -- the permanent inventory method:

$$RDcap_t = (1-\delta)RDcap_{t-1} + RD_t \qquad (0.5)$$

where δ is the depreciation rate.
The depreciation rate has to be assumed. We chose the 15 per cent rate as our base assumption, since it is most commonly used in the literature (Hall et al. 2010).[2] In order to calculate the own RD capital, we also need the approximation value for the first available year of R&D expenditures. The standard approximation formula was used:

[1] The research sector is defined as M72 in SBI2008 classification and K73 in SBI1993 classification.

[2] However, some argue that the depreciation rate may be as low as 10 per cent in the medium- and low tech industries, although the Dutch industry is mostly high tech. In any case, we have an alternative set of estimations with the 10 per cent depreciation rate as well. However, the returns to R&D expenditures over the lifetime of R&D investment are in this case not markedly different from those estimated with the 15 per cent depreciation rate.

$$RDcap_{t0} = RD_{t0} \cdot \frac{1+g}{g+\delta} \qquad (0.6)$$

where g in a sector specific real annual growth of value added over the period 1988-1993.

The external R&D capital can be based on two types on inter-sector transactions: purchase of intermediated goods, as recorded in an input-output table, or purchase of capital goods, as recorded in an investment matrix. The input-output tables are readily available from CBS and only needed to be aggregated to our 25-sectors classification. The investment matrix was constructed based on the annual investment flows in asset classes by sector recorded in the growth accounts of CBS. The asset classes were grouped into four categories directly corresponding to four investment-producing sectors: machinery and computers; transport equipment; construction; and software.

3 Estimation without intersectoral spillovers

The estimation results clearly depend on the choice of the deflators for the R&D expenditures, since the statistics report them in current prices, with three types of deflators mentioned above: the GDP deflators, the R&D sector output deflator and the R&D sector wage deflator. Regressions using the GDP deflator and the R&D sector output deflator yield similar results. Using the R&D sector wage deflator yields a slightly lower return to R&D expenditure. However, this deflator is based on the assumption of unchanging labour productivity in the R&D sector ("cost disease"), which is in our opinion not a very fitting assumption. Automation and other technological improvements in the research field make researchers more productive over time, just like in other economic sectors. Hereunder we present the estimation results based on the R&D sector output deflator, as we consider it the most fitting formulation. The results based on the GDP deflator are presented in the Annex.

The next table presents the estimation of the return to R&D without intersectoral spillovers, that is, under the assumption that no cross-benefits of the R&D expenditures occur among sectors. At the same time, the intrasectoral spillovers (that is, the benefits of R&D occurring in the same sectors where the expenditures are made) are being accounted for in this specification.

Table 2. Estimation of rate of return: dependent variable is the growth rate of value added.

	Lag (t-1)			**Lag (t-2)**		
	OLS	FE	RE	OLS	FE	RE
Δl_t	0.56***	0.57***	0.56***	0.53***	0.54***	0.53***
Δc_t	0.12	0.14	0.12	0.13	0.16*	0.14*
$RDint_{t-1}$	0.29***	0.24*	0.27***	-	-	-
$RDint_{t-2}$	-	-	-	0.22**	0.13	0.20**
Constant	0.01	0.02	0.04***	-0.004	0.02	0.04***
Obs	440	440	440	420	420	420
R^2	0.34	0.34	0.34	0.33	0.32	0.33

Where l, c, and RDint are, respectively, labour growth rates (in hours worked), ordinary capital growth rates, and R&D intensity based on the R&D stock[3]. The equation shows that the return to BERD expenditure of one euro in own sector is approximates 1.6 euro over the lifetime of R&D investment with the 15 per cent annual depreciation of the R&D stock. This follows from the sum of the geometric progression: return = 0.24/0.15 = 1.6.

[3] Small italic letters correspond to the natural logarithm of a variable.

4 Estimation with intersectoral spillovers

In order to account for the intersectoral spillovers, we took into account the R&D stock embodied in the product flows from other sectors. We have considered two types of spillovers:

- Spillovers via the R&D stock embodied in the intermediate flows recorded in the input-output table; and
- Spillovers via the R&D stock embodied in the in the purchased capital goods.

The annual flow into sector *i* of the R&D spillovers embodied in the purchases of intermediate products from all other sectors in year *t* can be expressed as

$$RDS_i^t = \sum_{\substack{j=1 \\ j \neq i}}^{n} RDC_j^t \frac{a_{ji}^t X_i^t}{X_j^t} \qquad (0.7)$$

where RDC_i^t – R&D stock in sector j, X_i^t – output of sector *i*, a_{ij} – direct requirement coefficients from the input-output table.

Then thus obtained annual R&D spillovers are converted into R&D spillover stock in each sector *i* via the permanent inventory method as specified in equations (0.5) and (0.6). Finally, the R&D intensity based on the change in the R&D spillover stock enters the familiar equation specification (0.4).
Similar procedure is carried out to evaluate the R&D spillovers embodied in the capital flows to each sector *i*. The annual flow of the R&D spillovers via capital investment is calculated as

$$RDSK_i^t = \sum_{j \in \Im}^{n} I_{ji}^t \frac{RDC_j^t}{X_j^t} \qquad (0.8)$$

Where, in addition to the already defined variables, I_{ji}^t is the element of the investment matrix (that is, the purchases of investment good *j* by sector *i* in year *t*, $\Im$ is the set of sectors producing capital investment goods (machinery and software).

The conversion of the annual flows of R&D spillovers to sector *i* to the R&D spillover stock generated via capital investment is carried out with the same procedure as for the own R&D stock and R&D spillover stock generated via the purchases of intermediate products, namely by the permanent inventory method. Then the respective R&D intensity appear in the equation (0.4), which now includes three coefficients of R&D returns: one for the R&D in the same sector, another for R&D spillovers through intermediate product, and the third for the R&D spillovers through capital investment. The estimation results follow.

Table 3. Estimation of rate of return: dependent variable is the growth rate of value added.

	Lag (t-1)			Lag (t-2)		
	OLS	FE	RE	OLS	FE	RE
Δl_t	0.58***	0.60***	0.58***	0.54***	0.56***	0.54***
Δc_t	0.10	0.13	0.11	0.11	0.16*	0.12
$RDint_{t-1}$	0.25**	0.21	0.24**	-	-	-
$RDint_{t-2}$	-	-	-	0.20*	0.07	0.17
$RDSint_{t-2}$	-0.25	-0.49	-0.32	-0.21	-0.50	-0.30
$RDSKint_{t-2}$	0.42**	0.43*	0.42**	0.36*	0.42*	0.37*
Constant	0.01	0.01	0.04***	-0.001	0.02	0.34***
Obs	431	431	431	420	420	420
R^2	0.35	0.35	0.35	0.33	0.33	0.33

Where $RDSint_{t-2}$ and $RDSKint_{t-2}$ are respectively R&D intensities based on the spillover via input-output and capital investment in machinery and software.

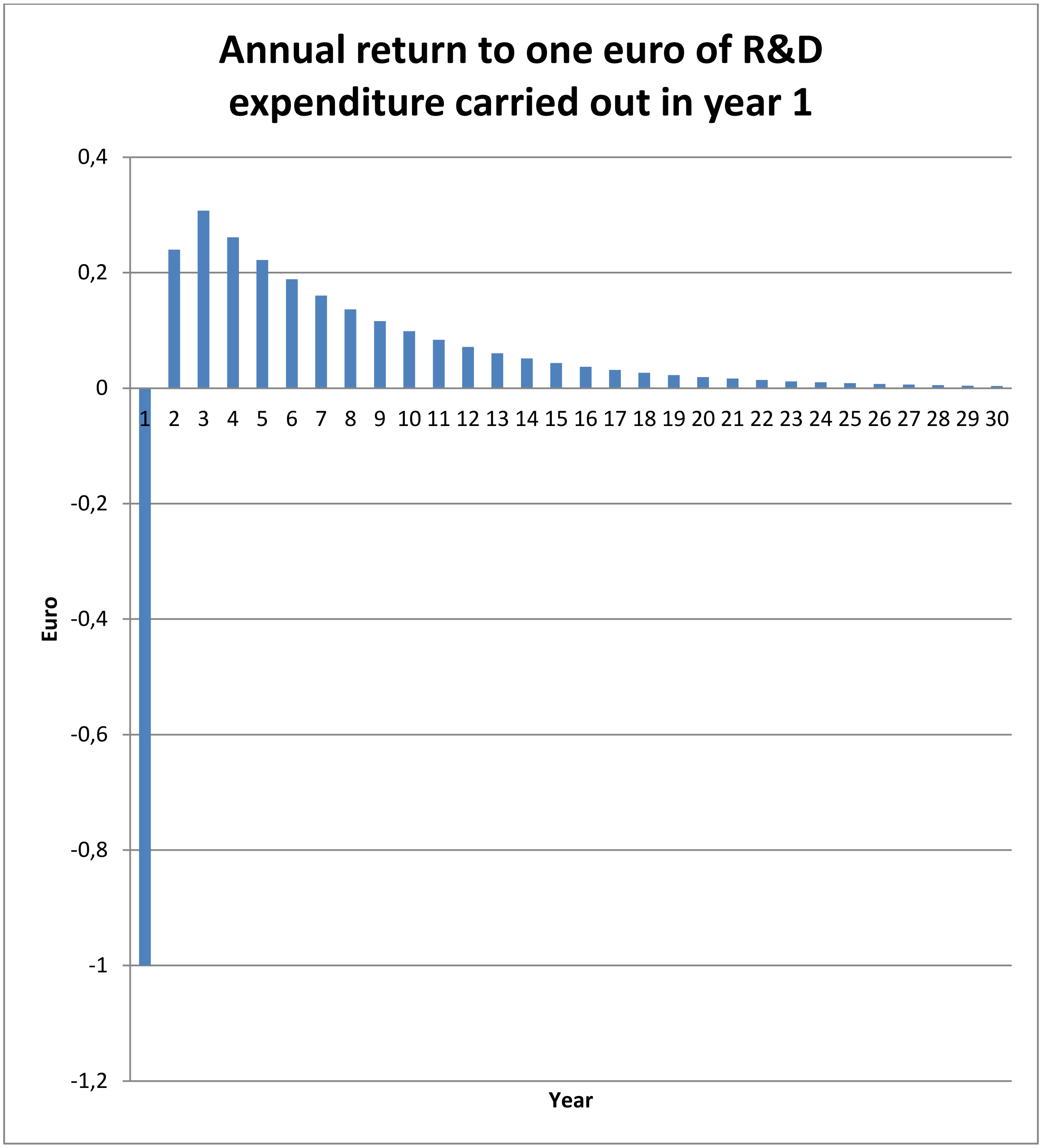
Given average values of the ratios given in equation (0.8), we estimate the spillover of the investment-producing sectors (machinery and software) in other sectors via capital investment in all other sectors is approximately the same as the return in their own sectors. One euro of R&D expenditures in investment sectors (machinery and software) will return 1.6 euro in the same sectors plus the same amount in all other sectors of the economy via increased productivity of all other sectors stemming from using more advanced machines, equipment and software with a high R&D content. Thus one euro invested in R&D yields two types of returns: return in the own sector -- 1.6 and the return of R&D in the investment sectors (which accounted for 43 per cent of total BERD) – 1.6*0.43. The total return thus equals 1.6+1.6*0.43=2.3. At the same time, we found no significant spillovers via the intermediate inputs, which is consistent with the literature. For example, Wolff and Nadiri (1993) found insignificant R&D spillovers via input-output intermediate flows while significant spillovers via investment matrix for the U.S.[4]

The temporal structure of R&D expenditure effects for one euro of R&D appear on Figure 1 and 2. There appears an inflexion point on the curve of the cumulative returns (Figure 2). This happens because of different lags of the effect of own R&D and spillover. The first year of the return to own-sector R&D happens one year after the R&D investment while the spillover return starts two years after the investment. The break-even point of occurs five years after the investment.

It is important to point out that these estimates refer to the lower-bound. Returns to ordinary capital and labour included in the R&D expenditures are already accounted for in the coefficients for capital and labour; thus this is the extra returns arising from the utilization of the R&D stock. In addition, we have accounted for only one type of spillovers.

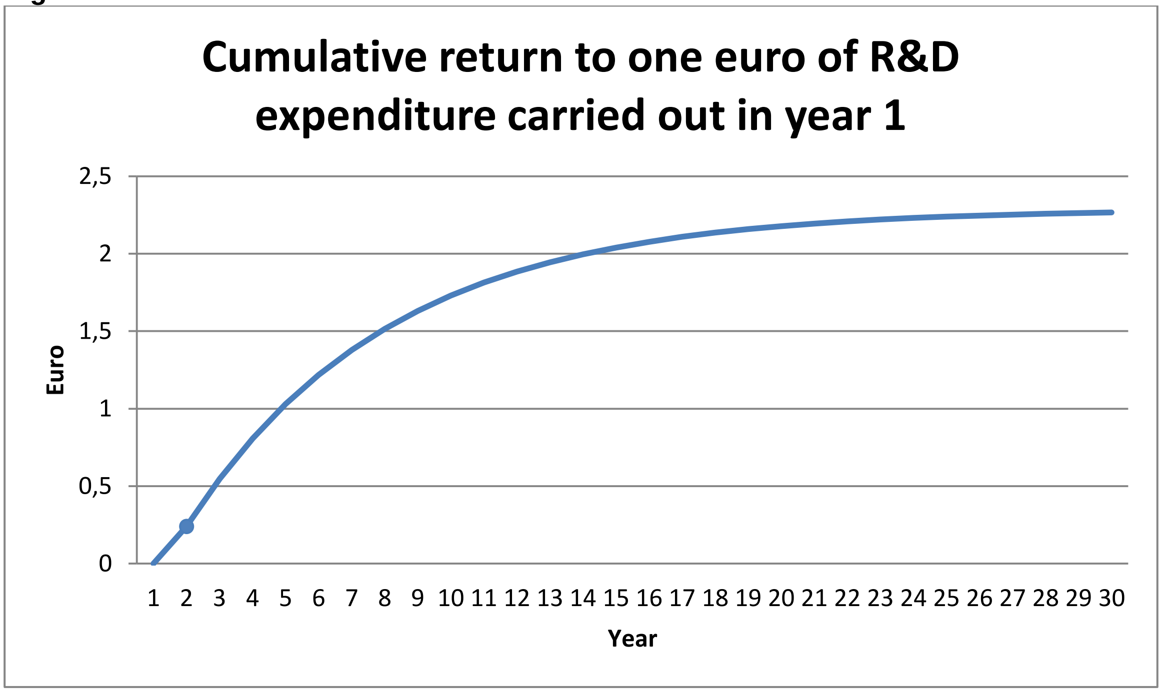
[4] However, Wolff and Nadiri's formulation of spillover via capital investment differs from ours.

Figure 1.



Annual return to one euro of R&D expenditure carried out in year 1
0,4
0,2
0
-0,2
-0,4
-0,6
-0,8
-1
-1,2
Euro
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Year

Figure 2.

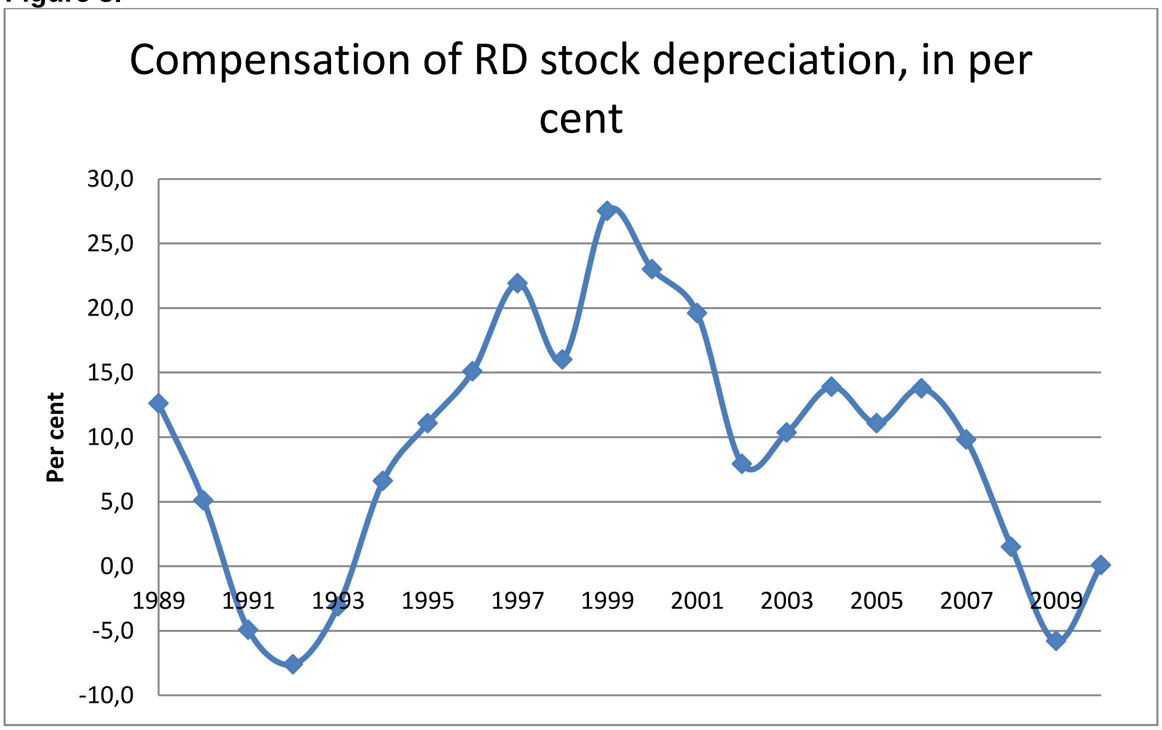


Cumulative return to one euro of R&D expenditure carried out in year 1
2,5
2
1,5
1
0,5
0
Euro
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Year

5 Dependence of economic growth on R&D stock

The above analysis shows a high dependence of the Dutch economic growth on R&D stock, since the accumulated R&D stock is quite large and the GDP growth and productivity rates are proportional to its increase. The high depreciation rate of knowledge (of 15 per cent annually) means that the Netherlands has to invest in R&D in order to have a non-negative positive effect on GDP by the R&D stock. The dynamics of the coefficient of the replacement of the R&D stock depreciation with R&D new investment is presented below.

Figure 3.



As seen from the figure, new R&D expenditures more than compensated the depreciation of the R&D stock (that is, the R&D stock was increasing) in all years except for 1991-93 and 2009. In 2010, the total BERD was just 0.1 per cent higher than the depreciation of R&D. The undercompensation of the R&D stock will affect the GDP growth two years after.

6 Using micro datasets for the estimation of returns to R&D and impact of government financing on business R&D expenditures

Microeconomic analysis was performed using microdata available through Centrum voor Beleidsstatistiek of CBS. For the purpose of the estimation of equation (0.4), a number of databases had to be merged. For the value added, labour and ordinary capital we used the micro dataset Productiestatistieken and for the R&D data we used the CIS and RTD survey data. Since the unit of observation in the three mentioned databases is a firm, another dataset, Algemeen Bedrijven Register which includes the registration detail and firms IDs, was used for linking the databases.

The CIS survey is performed every other year. Due to concerns over the quality of the data in the first CIS surveys we have included only the last four waves (2004, 2006, 2008 and 2010) in the analysis. The CIS respondents are a sub-sample of the whole population of Dutch firms and include both innovators and non-innovators (who do not spend on R&D). The RTD survey is performed also every other year alternating the years of the CIS survey and it includes only the firms which reported positive R&D expenditures in the preceding CIS survey. The CIS dataset was used for estimation of the main equation (0.4), since CIS has a higher coverage of firms than the RTD dataset. The RTD data provide more information on the sources of financing on R&D and therefore is used for the analysis comparing privately and government financed R&D.

The combined dataset represents an unbalanced panel of Dutch firms. The dataset was cleaned of unreliable outlying observations based on the inconsistencies between growth of value added, labour and ordinary capital. Highly innovative firms with R&D intensity over 70% were also excluded from the analysis.

The equation estimates are presented in the following table.

Table 4. Estimation of R&D rate of return: Dependent variable is the output growth rate over two consecutive waves of the survey ($\Delta va_t = va_t - va_{t-2}$). R&D data are based on CIS questionnaire.

	All employees	Correction for R&D personnel
growth rate of labour (all)	0.56***	-
growth rate of labour (excl. researchers)	-	0.55***
growth rate of capital	0.15***	0.10***
R&D intensity (t-2)	0.13***	0.12***
Dummy on innovators (t-2)	0.002	-0.0003
Constant	0.01***	0.01**
Obs	10090	5253
R^2	0.33	0.27

This equation confirms on the microdata the results obtained previously on the sectoral panel, that the growth of productivity and value added in dependent on R&D expenditures with a lag. However, we cannot build the R&D stock for individual firms: the survey panel is short in time and the surveyed firms change to a large extent from one wave to another. Therefore, we use the simple R&D intensity variable (that is, the ratio of the R&D expenditure over output).

While we thus far examined this question how much one euro of investment in R&D contributes to the higher output, the next question that we ask is, whether the return on R&D depends on the mode of financing. The ubiquitous view present in the literature is that public and private R&D investments have very different rates of return. Results of empirical analysis are ambiguous with respect to the effectiveness of instruments supporting (industry-oriented) research, and give a negative view concerning their efficiency. Yet, quite generally, privately funded R&D in manufacturing industries is found to yield a substantial premium over the rates of return from own productivity improvements derived from R&D performed with government funding. There is evidence in the literature that publicly-funded R&D expenditures have smaller effect on productivity than privately-funded (see David *et al.* 2000, Capron and Van Pottelsberghe 1997a for an overview).

Equation (0.4) with differentiated returns with respect to the mode of financing is presented below.

Table 5. Estimation of R&D rate of return: Dependent variable is the output growth rate over two consecutive waves of the survey. R&D data are based on the RTD questionnaire.

Δl_t - all	0.53***
Δc_t	0.14***
$RDint\_own_{t-2}$	0.20***
$RDint\_gov_{t-2}$	0.63
$RDint\_oth_{t-2}$	-0.01
D_innov_{t-3}	-0.01
Constant	0.03
Obs	1154
R^2	0.23

The results show that the return to privately-financed R&D are higher than to government financing on R&D (the latter being statistically insignificant), similar to the above literature results. Low return to R&D expenditures financed by the government can be explained by different types of projects financed by government and private funds. Government financing is used for the projects which are yet far from the market introduction and with high probability of failure. Privately-financed R&D project have a more immediate market potential.

7 Impact of public R&D on private R&D intensity

Now let us turn to the question on to what extent extra private investment in R&D is generated or supressed by government R&D financing. We first proceeded to estimate the log-linear equation linking privately-financed R&D expenditure with a (lagged) government financing (a specification similar although not equivalent to one in Capron and Van Pottelsberghe 1997b).

Table 6A. Estimation of the multiplier of public financing on private R&D expenditures: Dependent variable is R&D expenditures financed by own sources (fin_own).

	OLS	IV
fin_own_{t-2}	1.01***	1.02***
fin_gov	1.60**	0.31
Constant	-459.50	-279.00
Obs	1610	1611
R^2	0.81	0.81

The variable fin_gov is government financing of R&D expenditures.

Table 6B. Estimation of the multiplier: dependent variable is logarithm R&D expenditures financed by own sources ln(fin_own).

	No lag			Lag		
	OLS	IV	IV	OLS	OLS	OLS
$\ln(fin\_own)_{t-2}$	0.59***	0.58***	0.53***	0.59***	0.54***	0.54***
ln(fin_gov)	0.09***	0.11**	0.10*	-	-	-
$\ln(fin\_gov)_{t-2}$	-	-	-	0.05*	0.05	0.04
ln(fin_gov_sector)	-	-	-	-	-	0.05**
ln(turnover)	-	-	0.31***	-	0.30***	0.33***
Constant	2.29***	2.28***	-0.66*	2.43***	-0.54	-1.26***
Obs	1610	1610	1322	1611	1323	1279
R^2	0.37	0.37	0.40	0.37	0.40	0.40

The instrument for ln(fin_gov) is $\ln(fin\_gov)_{t-2}$.

The estimation results show no evidence of substitution of the privately-financed R&D expenditures with government financing on R&D. To the contrary there is evidence of the increased privately-finance R&D expenditures two years after the government subsidy on R&D; with the elasticity between 0.05 and 0.1: That is, one per cent increase in government R&D financing will lead to 0.05 to 0.1 per cent increase in privately-funded R&D expenditures two years after the subsidy is made. The elasticity of this magnitude is quite high since the share of government financing in BERD is low. In fact, any estimate above zero points to the multiplier effect of the government financing of R&D.

The high multiplier effect of the government financing on private R&D expenditures can be attributed to the firms using the government financing for the projects which are currently too far away from market to be financed by own means with an acceptable risk margin. When projects financed by the government show bigger market potential (after two years), private financing kicks in. Thus the government financing has a stimulating effect on private expenditures.

The output elasticity with respect to the change in R&D stock can be estimated based on the production function in levels (equation 0.2) or growth rates (equation 0.3). In the former case, the elasticity coefficient expresses the long-run relationship between the change in R&D stock and, in the latter case, the short-run relationship. In order to estimate the long-run elasticities, a cointegrating relationship among variables in levels is needed to be established (using, for instance, the dynamic least squares method). However, we were so far unable to establish a significant cointegrating relationship among variables but were successful in estimating short-run elasticity presented below.

Table 7. Rate of return to R&D: Dependent variable: the growth rate of value added

Without spillovers:

	Lag (t-1)			Lag (t-2)		
	OLS	FE	RE	OLS	FE	RE
Δl_t	0.53***	0.53***	0.53***	0.54***	0.54***	0.54***
Δc_t	0.10	0.13	0.11	0.11	0.16*	0.13
$\Delta rdcap_{t-1}$	0.07**	0.08**	0.07**	-	-	-
$\Delta rdcap_{t-2}$	-	-	-	0.01	0.01	0.01
Constant	0.01	0.02	0.04***	-0.003	0.02	0.04***
Obs	440	440	440	420	420	420
R^2	0.33	0.33	0.33	0.32	0.32	0.32

Including spillovers:

	Lag (t-1)			Lag (t-2)		
	OLS	FE	RE	OLS	FE	RE
Δl_t	0.56***	0.58***	0.56***	0.55***	0.56***	0.55***
Δc_t	0.07	0.12	0.08	0.09	0.15	0.11
$\Delta rdcap_{t-1}$	0.06*	0.08*	0.06*	-	-	-
$\Delta rdcap_{t-2}$	-	-	-	0.01	0.02	0.01
$\Delta rdscap_{t-2}$	-0.03	-0.14	-0.07	-0.04	-0.17	-0.09
$\Delta rdskcap_{t-2}$	0.11*	0.12*	0.11*	0.12*	0.13**	0.12**
Constant	0.02	0.01	0.04***	-0.001	0.03	0.04***
Obs	431	431	431	420	420	420
R^2	0.34	0.34	0.34	0.32	0.32	0.32

The estimates of the elasticity without spillovers range from 0.06 to 0.08. The spillover effect adds another 0.015 (with a lag of two years) to the elasticity coefficient thus yielding the overall elasticity with respect to R&D stock of 0.075-0.095.

8 Conclusions

1. This study has examined the average rate of return to one euro invested in R&D in the Netherlands in the last 20-plus years carried out by private enterprise. It concluded that one euro spent on R&D returned, on average, at least 2.3 euro over the lifetime of investment, including 1.6 euro in the sector where the R&D was carried out and an extra 0.7 euro via the purchasing of investment goods (machinery and software). There are time lags between one and two years from the time of the R&D expenditure and the start of return to the investment. These results were obtained on the basis of sectoral panel from 1988-2010 for 25 sectors (including agriculture, mining, 16 industrial and 7 service sectors).

2. The Dutch economy is highly dependent on the accumulated R&D stock. The compensation of the R&D stock was lower than its depreciation in four years since 1988-2010, including in 2009. In 2010, the depreciation of R&D stock was almost exactly compensated thus allowing no growth of the stock.

3. Micro datasets (CIS, RTD) allowed the estimation of rates of return to R&D on the firm level. It confirmed the conclusion of high positive return to R&D with a time lag of up to two years. Specifying differentiated returns by source of financing showed that the return to privately-financed R&D are higher than to government financing on R&D, similar to the results for other countries found in the literature. Low return to R&D expenditures financed by the government can be explained by different types of projects financed by government and private funds.

4. The estimation results show a high multiplier effect of the public R&D financing on privately financing with a two year time lag with the elasticity between 0.05 and 0.1. The elasticity of this magnitude is quite high since the share of government financing in BERD is low.

5. The estimates of the short-term elasticity of output with respect to R&D stock without taking account of intersectoral spillovers range from 0.06 to 0.08. The spillover effect adds another 0.015 (with a lag of two years) to the elasticity coefficient thus yielding the overall elasticity estimate of 0.075-0.095.

References

Capron H. and B. Van Pottelsberghe (1997a). "Public support to business R&D: asurvey and some new quantitative evidence". OECD Conference on Policy Evaluation in Innovation and Technology (26-27 June 1997) Available at www.oecd.org/sti/innovationinsciencetechnologyandindustry/1822815.pdf

Capron H. and B. Van Pottelsberghe (1997b). "Issues in measuring the relationship between government and private R&D", Economic Systems Research, Taylor and Francis Journals, vol. 9(4): 331-356.

David, P.A., Hall, B.H., Toole, A.A. (2000). "Is public R&D a complement or substitute for private R&D? A review of the econometric evidence", Research Policy 29 (4-5): 497-529.

Hall, B.H, J. Mairesse and P. Mohnen (2010). "Measuring the returns to R&D". In Hall and Rosenberg (editors), Handbook of the Economics of Innovation, Volume 1, 2010.

González, X., Jaumandreu, J., Pazo, C. (2006). "Barriers to innovation and subsidy effectiveness,"

Mairesse, J. and P. Mohnen (2010). "Using innovation surveys for econometric analysis". Handbook of the Economics of Innovation, Volume 1, 2010.

Wallsten, S.J. (2000). "The effects of government-industry R\&D programs on private R\&D: the case of the Small Business Innovation Research program," The Rand Journal of Economics 31(1): 82-100.

Wolff, E.N. and M.I. Nadiri (1993). 'Spillover effects, linkage structure, and research and development', Structural Change and Economic Dynamics 4(2): 315-331.

Vitae

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