Subsidies, Human Capital and Business R&D

Volker Reinthaler* and Guntram B. Wolff**

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Abstract

We investigate the role of several macroeconomic factors in explaining business sector research. Thereby we focus on the human capital and various forms of public policy. We depart from the literature by (a) using data of expenditure and employment in private research, which allows us to estimate a structural model, and by (b) extracting cross-section and time-series information of an OECD data set. Our main findings are: (i) Direct subsidies to R&D have only little long-run influence on the R&D investment decision. For the short run, we can confirm the relatively large effect found previously in the literature. (ii) In contrast, human capital shows no effect in the short run, but a positive and significant one in the long-run regression.

*Universitat Pompeu Fabra and University of Bonn, e-mail: Volker.Reinthaler@econ.upf.es

**ZEI - Center for European Integration Studies, University of Bonn, Walter-Flex Str. 3, 53113 Bonn, Tel: 0228/73 - 1887, e-mail: gwolff@uni-bonn.de

1 Introduction

Research and Development has been identified as one of the principal sources of economic progress. It leads to innovations and discovery of ideas, which in turn enhance productivity and generate growth. It is therefore important to study the factors driving research and development.

In the patent race literature and the new endogenous growth theory of the 1990s (Aghion and Howitt (1998), Romer (1990)), the sources of technological progress are endogenous to the choices of economic agents. Furthermore the innovations are the source of growth of the entire economy. Aghion and Howitt (1992) develop a model, in which firms invest into R&D in order to innovate. The innovation allows to monopolize markets and thereby generate true profits. Thus the firm has an incentive to undertake research. The amount of research undertaken becomes endogenous to profit expectations. These will, in turn, depend on macroeconomic conditions like the interest rate and human capital levels.

This literature also identifies markets failures leading to an under-provision of private research. Firms, so the argument, do not take into account the spillovers of their research to research undertaken by the other firms and thereby to general technological progress. This market failure calls for public measures to increase the speed of innovation. In fact all OECD countries subsidize the private sector research to overcome this market failure.

Many studies have investigated the effectiveness of subsidies in leading to more research, for a survey see David, Hall and Toole (2000). Most of the studies concentrate on the the effectiveness of specific programs at a firm level. These microeconometric studies are, however, problematic for the following reason. Wallsten (2000) points out that while studies on a firm level usually find a correlation between employment and grants, it cannot determine whether grants are given to those firms that do a lot of research or whether firms do a lot of research because of the grants. Kauko (1996) also argues that the effect of subsidies in rather low on a micro level if one controls for the endogeneity of subsidies. In addition, increasing subsidies for one firm could lead to "migration" of scientists from one firm to another, leaving the total amount of research unaffected. This critic is sometime met with the argument that the government can target subsidies to those firms that perform research of special relevance for the entire economy. However, there is no evidence given that the government knows better than the business sector, which research is especially promising. Therefore we investigate the effectiveness of subsidies in increasing the total number of researchers in the economy's business sector on a macroeconomic level.

On a macroeconomic level, only few studies have been performed.[1] They find a positive link between government subsidies and privately funded research expenditure. Their analysis is however usually constrained to short time series, with the exception of Levy (1990) and Guellec and Pottelsberghe (2000), who employ panel data.

The usual approach to evaluate the effectiveness of the subsidy in macroeconomic studies is to regress private expenditure on the subsidy and a number of control variables. This approach, however, is problematic for a number of reasons. First of all, private expenditure and subsidies are both procyclical. The coefficient of the subsidy will then capture the effect of the business cycle and not the true impact of the subsidy. Second, strong increases in subsidies will, when effective, increase the demand for research input, namely scientist. This in turn could, depending on the supply elasticities of scientists, induce large increases in wages. Goolsbee (1998) finds that subsidies to firms for R&D have significant wage effects. The estimated coefficient can thus wrongly estimate the true impact of the subsidy, in the extreme case of completely inelastic supply, the subsidy will have no real effect, but only a wage effect. In addition, the wage rate after the subsidy can fall, thus leading to reduced private *expenditure*, but increased private employment. The coefficient would thus underestimate the real impact of the subsidy.

We therefore propose an approach which is more robust. We regress the number of researchers as the dependent variable on the average subsidization rate.[2] We investigate whether the average subsidization rate in the economy has an effect on the actual number of researchers in the business sector. Thereby we can overcome the problem of changing wage rates and of business cycle dependence.

Numerous papers investigate the role of human capital for research and productivity. Barrio-Castro, López-Bazo and Serrano-Domingo (2002) find that the total factor productivity to human capital elasticity is around 0.5, much higher than previously estimated by Engelbrecht (1997). One can think of at least two links why human capital is important for business research. On the one hand the number of people with university degrees constitute a pool from which to draw new researchers. The increased supply will lower wages and thereby increase the number of profitable research projects and the number of researchers. In addition, if the level of qualification is high, the demand for technically advanced products is higher. This holds for the private consumption of new products as it is true for the business sector, which can only use technically advanced products, if their employees can handle

[1] Diamond (1999), Levy (1990), Robson (1993), Lichtenberg (1987), Levy and Terleckyj (1983), Guellec and Pottelsberghe (2000)

[2] It would be nice to have figures on capital employed as well. This data is not available, however.

them. This effect is called skill-biased technical change in the literature (Acemoglu 2002). In both cases higher human capital will increase the research activity.

Our choice of the additional regressors is based on insights from the new endogenous growth theory. We test whether these macroeconomic variables indeed have any explanatory power for business research. Among the macroeconomic variables are the average tax rate in the economy and the long term interest rate. The new growth theory predicts that both variables should be negatively linked to private research activity. The openness of the economy reflects business opportunities abroad (demand factor) and is also a measure for international R&D spillovers (supply factor). Coe and Helpman (1995) show that the technical progress of a country depends on foreign R&D effort that spills over by means of trade. In contrast, Kao, Chiang and Chen (1999) find that the spillover effect of foreign R&D is low when using long-run estimation techniques.

Empirically we differentiate between short run and long run effects of the variables. We estimate a panel specification with OECD data. The fixed effect estimator exploits the time series information content of the data. According to conventional wisdom, e.g. Griffin and Gregory (1976), however, time series data yield short run responses. Baltagi and Griffin (1984) rigorously investigate the short and long run responses in pooled (macro-)models, and show that the within estimator gives the short run response. To capture the long run response, OLS is the preferred method. We thus estimate our model with OLS and do the appropriate corrections of heteroscedasticity for the estimated standard errors by employing Beck and Katz (1995b)'s methodology to have the long run coefficients.

Our results indicate that the short run effects of a change of the subsidization rate on the number of employed researchers are substantial. An increase of the aggregate subsidization rate from 13 to 14 percent will increase private research activity by 1.2 percent. In the long run this effect is much smaller; the number of researchers increases by only 0.5 percent. In the short run the increase of the subsidy by 1 dollar will generate 0.7 dollars additional private funds. In the long run, however, the subsidy does not generate any additional private funds. Human capital of the society contributes to additional research in the long run. Changes in tax rates have a negative effect. Our findings thus support elements of the new growth theory. In addition, we show that subsidies are effective. However in the long run they do not generate additional private funds. Human capital plays a crucial role for long run research differences between countries.

The remainder of the paper is structured as follows. The next section reviews the theoretical literature and gives a foundation of our empirical approach. We then present the data and in section 4 we present the estimation results for the long run and short run effects of subsidies, human capital and macroeconomic variables.

2 Inside the R&D black box

As argued in the introduction, we are interested in the factors that determine the R&D investment of private firms. Among these factors we are especially interested in the effectiveness of public subsidies. In the following section we will first discuss the principal determinants of R&D as put forward by the theories of endogenous technological change. We will then have a closer look on how to evaluate direct public subsidies.

2.1 Principal Determinants of R&D

What are the factors that determine private investment in research and development? In order to analyze systematically the decisions of private firms to perform R&D, we follow the approach used to model the innovative process in R&D-based growth theory [e.g. Romer (1990), Aghion and Howitt (1992)]. The idea can be summarized as follows. Profit maximizing firms have an incentive to invent better products in order to monopolize the market for at least some time. Since the economic profits corresponding to the temporary market power should cover the initial expenses for research, the total amount or R&D in an economy is endogenously determined. Equilibrium R&D is determined by the point where marginal cost equal marginal expected revenues, we will now have a look at the cost and benefits of private research and its appropriable returns.

Cost of research basically depends on the availability of research inputs, namely capital and highly qualified labor. Whenever there are, e.g. only few researchers in an economy, firms have to pay high wages in order to attract them. But high wages imply that some projects cannot be undertaken since cost exceed expected profits. Whereas it es rather easy to proxy the availability of qualified labor by the fraction of university graduates in the population, it is quite difficult to measure the availability of capital for innovative projects. The capital cost can be measured directly by the long run interest rate. However, the development of stock markets for venture capital also plays an important role. One very direct determinant of the cost of R&D are public subsidies. At least in the developed countries, all governments fund business for carrying out research. The funding takes place either under procurement programmes, in which case the R&D result is property of the government, or is paid as a grant.

The benefits to R&D correspond to the discounted future profits in case the innovation was successful. Thus, the expected revenue is composed of two parts, the probability of innovation and future profit opportunities. (i) The probability of innovation - sometimes called 'arrival rate of innovation' - is likely to depend on the amount of basic research performed in universities or other public (or semi-public) research institutions. There is not only the possibility of direct spin-offs, firms and universities can cooperate directly, Ph.D students contribute their knowledge to the research department of their future employers and so on. Firms profit from positive external effects associated with basic research. (ii) Expected future profit opportunities depend on the market size and the expected growth rate in the sector where the innovation takes place. On the macro level one can capture the market size by the GDP corrected for tax and trade. Whereas a high tax ratio decreases future profits, trade may proxy the possibility for firms to sell their products in foreign markets. The openness of the economy thus reflects profit opportunities abroad on the one hand. In addition, more open economies have more access to foreign technology, there can be substantial spillovers. However, Kao et al. (1999) estimate that these spillovers through trade are of minor importance in the long-run.

2.2 Direct Subsidization of R&D

Let us now evaluate the short-run-effectiveness of direct subsidies to business R&D. The usual approach in the literature is to analyze whether public and private R&D expenditure are complements or subsidies. In other words, one tries to figure out whether public subsidies generate additional private expenditure or crowd out private spending. However this approach is problematic. Let us consider briefly a simple model in order to get some structure in the problem.

Assume for simplicity, that qualified labor (human capital) is the only input in research.[3] There is a large number of R&D-projects with different returns. By ordering the projects one obtains the downward sloping inverse demand function $w_t^d = D(L_t^d)$ where w^d is the expected return that could be generated by the L'th. researcher in the economy. Let the supply of researchers be described by $w_t^s = S(L_t^s)$. The government can subsidize research at the rate β. For every dollar that private firms spend on R&D, they receive additional β dollars from the government. The equilibrium is determined by the amount of research for which $w^s = (1 + \beta)w^d$.

Note that we are implicitly assuming that the government cannot target subsidies to specific firms or projects. However, the performance of governments in targeting subsidies cannot be evaluated in empirical macro-studies anyway. Therefore we

[3]Romer (2000) points out that in university research only 5 to 7 percent is spent for equipment.

assume β to be the average subsidization rate as defined by the ratio of total public over total private expenditure in R&D.

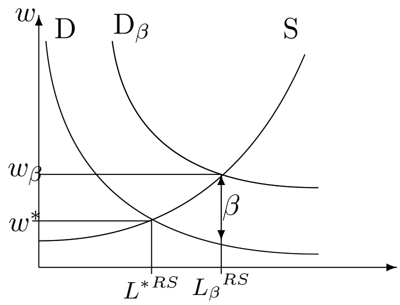

Figure 1: Short run effect of R&D-subsidy

As one can see in figure 1, the amount of research L and total expenditure in R&D $(1+\beta)wL$ clearly increase with public subsidization. However, the effect on private expenditure wL is a priori ambiguous. Estimating the relationship between private expenditure and the subsidy will therefore not give any relevant information on the true effects of the subsidy on real research activity. By estimating the impact of public expenditure βwL on private expenditure wL the literature is underestimating the effectiveness of R&D subsidies on actually performed research. The only sensible measure for evaluation purposes is the quantity of research, since the evolution of private expenditure depends on the elasticities of labor supply and labor demand.

Let us have a closer look at labor supply. Goolsbee (1998) argues that labor supply is relatively inelastic in the short run. There is evidence that subsidies to research firms in the defence sector basically increase the wage of employed scientists. The impact on the hours worked is rather small. In this case, i.e. with a vertical labor supply curve in figure 1, employment and private expenditure does not depend on the subsidization rate.

On the other side, there are arguments why labor supply could be rather elastic at the macro level, even in the short run. The fraction of qualified labor - e.g. employees with university degree - employed in research departments is rather small. In the most developed countries, e.g. US, Japan, Germany, Great Britain, it is about 3 %. In all the other countries in our sample it is considerably smaller, in general less than 1 %. Additionally, the ratio of research performed in private entities as compared to universities and other research institutions is about 50 %. So it should not be impossible for private firms to hire new employees for their research departments. Consider the extreme case of totally elastic labor supply. In this case, total expenditure increases by the same proportion as labor itself. The effect on private expenditure is still unclear.

What should we observe in the data if R&D-projects were completely inelastic, i.e. if the demand-curve for R&D-labor was vertical? An increase in the subsidization rate β would only decrease the cost for private firms, hence employment and total expenditure remain unchanged and private expenditure decreases.

2.3 Regression equation

Our estimated equation differs from the approach usually taken in the literature. We opted for a different approach by choosing as the dependent variable the real number of researchers in the business sectors for several reasons. By looking at the number of researchers we look at a direct measure of R&D investment, which is not subject to endogenous wage changes. Furthermore we overcome possible omitted variable problems of previous studies due to general wage changes, which will affect the subsidies as well as private expenditure. We use data on R&D expenditure of the private sector and on R&D employment as provided by the OECD. This allows us to get an idea of whether these factors have a real effect on R&D inputs or just increase the level of prices/wages and boost cost.

Employment in research departments is they only available data on "quantities" used in research. Wages represent a large part of total spending.[4]

$$\begin{aligned} ln\left(L^R\right)_{it} &= \alpha_0 + \alpha_1\beta_{it} + \alpha_2\left(\frac{T}{Y}\right)_{it} + \alpha_3\left(\frac{X+M}{Y}\right)_{it} + \alpha_4\left(\frac{herd}{Y}\right)_{it} + \alpha_5 ln\left(\frac{Y^*}{L}\right)_{it} \\ &+ \alpha_6 ln\left(\frac{H3}{L}\right)_{it} + \alpha_7 ln\left(L\right)_{it} + \alpha_8\left(\frac{goerd}{Y}\right)_{it} + \alpha_9 r_{it} + u_{it} \end{aligned} \quad (1)$$

As explanatory variables we include the subsidization rate β. The business cycle, inflation and other factors can have a simultaneous impact on both private expenditure and the subsidy. Neglecting one of these factors lead to an upward bias of the corresponding coefficient. By using $\beta = \frac{E^{pub}}{E^{priv}}$ we get rid of this problem. As discussed in the last section, we expect the coefficient for the subsidization rate to be positive, its size depends on the demand and supply elasticities in the market for researchers.

We also include the public expenditure for research in higher education institutions (*herd*) and research in other government funded institutions (*goerd*). Both should have a positive impact on business R&D through spillovers.

[4]Although the subsidy could also affect the use of equipment, it is not the primary intent of a subsidy to increase the capital intensity of research. If this was the intent, the subsidy should be specifically aimed at promoting capital. Therefore, it is a valid approach just to investigate the reaction to a subsidy in terms of the number of employed researchers. Certainly, people constitute the most important "input" to research.

In order to caption the impact of taxation, we include the average tax rate, i.e. the ratio of total tax income over GDP. There are better measures like the B-index of the OECD that summarizes the taxational treatment of R&D investments. It corrects for special tax allowances and other institutional determinants. Unfortunately it is not freely available. On the other side, according to the endogenous growth theory, all kind of taxes influence the R&D decision through the demand-channel. For example, a consumption tax reduces the available income for households and therefore their spending for innovative goods. The average tax rate summarizes the tax system but neglects the special structure of tax allowances. Other variables that measure the market size and capture profit opportunities for research firms are the standard measure of openness, GDP per capita and population size. All of those variables are expected to have a positive impact on R&D employment.

We finally include variables that represent the cost of research. The interest rate captures the funding cost of R&D projects. The proportion of labor force that has a university degree proxies the relative availability of potential researchers, a factor that could influence the wage cost. For detailed description of the data set we refer to the appendix.

2.4 Static and dynamic effects

Most of the explanatory variables have a different impact in the short and in the long run. There might be intertemporal spillover effects that reinforce or weaken several effects. Also time-to-build is a relevant issue. In this section we will concentrate on explanations of why the impact of (a) direct subsidies and (b) human capital has a static and a dynamic component.

As seen in section 2.2, the effectiveness of government subsidies depends on the slope of the demand and of the supply curve for researchers. Both are likely to have a different shape in the short and in the long run. Labor supply will probably be more elastic in the long run. In the short run, the number of qualified employees is fixed, since it takes some time for young people to get educated. However, when young people decide on their field of study they take into account expectations on future employment probabilities and salaries.

Regarding the demand for researchers, which depends on the number of potential R&D projects, there are arguments in both directions. On the one hand it could be, that subsidized research helps to foster a new technology which in turn induces other firms to build on that technology. For example the information technology was subsidized a lot in the beginning, and after some time also private firms started to do research in this area. That would imply that the number of ideas is very elastic in the long run since single ideas build upon each other. This effect is called technology spillover effect in the growth literature, see for example Barrio-Castro et al. (2002). On the other hand it is plausible that the institutional setting on the micro level leads to an aggregate demand for researchers that is more elastic in the short- than in the long run. There are four kind of intertemporal substitution effects: First, a within-firm effect. A individual firm that receives a government grant initially increases the number of researchers. But when time goes by, it does not replace retired employees in other projects or even shuts down other R&D-projects. Second, there could be a between-firm substitution effect. Subsidized research in one firm crowds out research done originally in another firm. Third, the inter-sectoral effect. By deciding to foster one special sector, different sectors might suffer. This is likely to be the case in industry development programs where regions try to attract firms of one special sector. Finally, there might be some international substitution such that research in one country makes firms in other countries to stop their R&D projects.

The impact of an increase of human capital might also be different in the short and in the long run. The number of employees with university degree determines the position of the labor supply curve. Following the arguments of Acemoglu (2002) however, the direction of a shift of the supply curve due to an increase in human capital is ambiguous. In the past 60 years one observes a steady increase of qualified labor, but not the expected decrease in relative wages. This pattern is typically explained by skill biased technological change. In the long run high human capital levels might lead to more technical change and research favoring human capital and thereby increasing human capital. In contrast, in the short run a positive shock to human capital will probably lead to decreasing wages and therefore reduces the cost of research.

3 Data

Table 1 reports the summary statistics of the data for the sample[5]. The average subsidization rate β in the sample[6] varies between 1.58 percent of business expenditure in Japan and 31.9 percent in France. The human capital endowments of the countries under investigation exhibit strong variation. While in Italy only 6.4 percent of the population have non-university tertiary and university education, in Canada more than 40 percent have this qualification. The percentage of researchers in the business sector in population is less than 0.4 percent in all OECD countries. The magnitude of variation, however, is equally of order 20. Average taxation rates vary between 14 and 44 percent. Higher education R&D outlays represent between 0.1 and 0.5 percent of GDP. The openness of the economies varies between 20 and 110 percent, average per capita income in 1991 PPP-$s is between 9 and 18 thousand.

	β	$H3/L$	L^{RS}/L	T/Y	$herd/Y$	$(X+M)/Y$	Y^*/L
Canada	13.92	43.30	0.19	17.48	0.35	55.61	18858
Germany	14.21	18.38	0.42	28.68	0.42	56.81	17165
Denmark	10.86	19.21	0.26	32.89	0.35	68.42	17789
Spain	11.42	9.22	0.06	26.79	0.18	40.25	11701
Finland	4.53	19.96	0.28	27.38	0.38	56.41	15226
France	31.92	19.72	0.26	37.78	0.34	44.77	16628
United Kingdom	28.99	13.54	0.30	32.58	0.34	52.40	15393
Greece	11.22	11.46	0.02	23.70	0.12	35.93	9440
Ireland	11.52	11.71	0.07	34.51	0.16	109.77	10093
Italy	20.13	6.36	0.10	36.02	0.23	42.86	16028
Japan	1.58	20.55	0.41	14.30	0.55	21.14	17252
Netherlands	12.62	14.29	0.20	44.55	0.51	104.49	15053
Norway	23.45	15.53	0.24	33.03	0.40	71.89	18215
New Zealand	7.80	23.57	0.08	37.00	0.24	44.84	14016
Portugal	6.21	6.80	0.02	28.88	0.18	68.74	10240
Sweden	12.93	19.16	0.40	36.25	0.83	62.60	16297

Table 1: Summary statistics in percent, or 1991 dollar equivalent; sample mean.

All variables exhibit strong cross country variation. Variation in time is in some cases quite limited. Employment and human capital in the economies are rather stable over time, both variables slowly increasing over time in all countries.

[5]The sample is unbalanced, some of the presented data therefore are not the mean over the entire period 1981-1997, but over shorter periods.

[6]For the USA there were no data available for researcher employment in the business sector in the OECD data set. In addition, we suspect that the US are a special case, since there is substantial immigration of scientists and engineers to the US, so that supply reacts differently from the other states. Romer (2000) gives detailed figures on the number of foreign students graduating from US universities.

4 Determinants of R&D: Empirical Evidence

4.1 Methodological issues

Equation (1) is a panel regression specification. The purpose of this section is to discuss a number of methodological issues connected to the panel specification. Especially we will highlight the difference between long run and short run responses of the dependent variable to changes in the explanatory variables.

Baltagi and Griffin (1984) investigate the ability of various estimators in capturing short and long run effects in pooled data. Starting point of their paper is the observation that applied researchers often find differences in their estimated coefficients between the within-estimator and for example the between-estimator. The old explanation is that time-series data reflect short run responses, while cross section data give long run responses. The fixed effect estimator (within-estimator) essentially explores the time dimension of the data, since the level effects are cancelled out by the fixed effects. The between-estimator on the other hand explores the cross section level differences.

In a first step Baltagi and Griffin analytically show under which conditions an estimator gives the long run effect. In case of a dynamically underspecified model, the estimated coefficient in an OLS regression will capture the contemporaneous effect plus the sum of all past effects multiplied with the autocorrelation of the variable. A dynamically underspecified model is a model in which past explanatory variables, which have an effect on the contemporaneous variable, are neglected. The authors show, that in applied research it is very likely that you choose an underspecified model. In addition, short available time series do not allow to specify a model with large lag length. In our case, the number of time periods is very limited. In addition, it is plausible to assume that changes in human capital level will have an effect in later years, as firms need time to adopt their behavior.

In a second step, Baltagi and Griffin show with Monte Carlo simulations of a Macro panel of similar size as ours that time series data essentially reflect short run responses. They present evidence that the within-estimator best captures short run effects of the independent variables. The OLS estimator on the other hand gives very robust estimates of the long run effects under alternative degrees of misspecification. We therefore present the results of the within estimator and of simple OLS regressions and interpret the results as short-run and long-run effects. To get the appropriate standard errors, we employ panel corrected standard errors as proposed by Beck and Katz (1995b).

4.2 Regression Results

Table 2 reports the basic regression results for the short run, table 3 presents the results of the long run estimates. The set of regressors with the fixed effect estimator explains around 60 percent of the variance of employment and around 80 percent of the spending. If we exploit the time series and cross section content of the data, 99 percent of the variance can be explained. In the following we will discuss the estimation results by variables. First we will focus on public policies, especially subsidies. Then we will discuss the results concerning macroeconomic determinants. In a last step the importance of human capital is stressed.

	$\ln(L^{RS})$			$\ln((1+\beta)w * L^{RS})(ppp)$	$\ln(w * L^{RS})(ppp)$
	1	2	3	4	5
β	1.19	1.05	0.96	1.47	0.66
	5.60	4.44	3.97	7.29	3.26
$\frac{T}{Y}$	-1.03	-1.07	-1.08	-1.12	-1.16
	-2.04	-2.11	-2.19	-2.33	-2.41
$\frac{X+M}{Y}$	0.39	0.47	0.27	0.16	0.16
	2.15	2.48	1.45	0.92	0.90
$\frac{herd}{Y}$	7.54	5.64	6.61	5.13	5.18
	2.77	1.87	2.37	1.99	2.00
$\ln(\frac{Y^*}{L})$	1.42	1.49	1.27	2.07	2.07
	6.28	6.46	5.56	9.66	9.63
$\ln(\frac{H3}{L})$	0.08	0.08	0.09	0.20	0.19
	0.40	0.42	0.44	1.09	1.08
$\ln(L)$	0.68	0.65	0.54	0.96	0.97
	2.52	2.39	1.95	3.71	3.77
$\frac{goerd}{Y}$		0.04			
		1.43			
interest rate			0.00		
			0.60		
constant	-5.53	-6.15	-3.51	-14.85	-14.89
	-1.88	-2.07	-1.17	-5.33	-5.33
Obs	198	198	179	198	198
R^2	0.636	0.64	0.56	0.799	0.809

Table 2: Regression results for the short run.

4.3 The influence of public policy on business research

In all specifications of the short run, β has a positive impact on the number of researchers. The coefficient is of magnitude 1.1 and is significant on a 1% level.[7] The point estimate for β is slightly higher in the regression with total research expenditure in the private sector as the dependent variable. Increasing β, the rate of public funding in private funding, by one percentage point will increase private

[7] In all regressions reported in table (2) we studied the correlations between the independent variables to make sure that our results are not driven by collinearity problems. The maximum correlation is between $\frac{herd}{Y}$ and $\ln(\frac{Y^*}{L})$ with 0.7. Dropping $\frac{herd}{Y}$ has no impact on magnitude and significance of the other variables, the coefficient for $\ln(\frac{Y^*}{L})$ becomes slightly larger and picks up the effect.

	$ln(L^{RS})$			$ln((1+\beta)w * L^{RS})$	$ln(w * L^{RS})(ppp)$
	1	2	3	4	5
β	0.49	0.46	0.49	0.47	-0.06
	2.93	2.84	2.96	3.14	-0.26
$\frac{T}{Y}$	-0.33			0.15	-0.05
	-0.93			0.52	-0.12
$\frac{X+M}{Y}$	0.09	0.07		0.15	0.23
	0.60	0.50		1.37	1.31
$\frac{herd}{Y}$	7.01	5.64	5.47	14.65	11.56
	3.31	2.29	2.71	9.17	4.40
$ln(\frac{Y^*}{L})$	1.24	1.22	1.30	1.64	2.00
	5.69	5.68	5.97	12.11	8.40
$ln(\frac{H3}{L})$	0.48	0.52	0.52	0.21	0.34
	3.77	3.71	3.91	2.99	2.56
$ln(L)$	1.16	1.16	1.15	1.13	1.23
	19.81	20.08	22.62	37.15	22.84
constant	-4.48	-4.24	-4.96	-11.14	-15.32
	-2.03	-1.90	-2.22	-8.16	-6.45
R^2	0.99	0.99	0.99	0.99	0.97
Obs	198	198	198	198	198

Table 3: Long run responses.

employment of researchers by roughly 1.1 percent in the short run. The impact on total business spending for research is rather small. Regression (5) allows to quantify the impact of a change in β on private research spending. Increasing β by one percentage point will lead to an increase of private research expenditure of 0.66 percent. In other words, if the government increases beta by 1 percentage point (from 0.13 to 0.14), private expenditure will increase 0.66 percent. One can calculate that an increase of 1 dollar of government subsidies will generate an increase of private subsidies of 66 cents.[8] This effect is comparable with the results of earlier literature. Guellec and Pottelsberghe (2000), for example, find that 1$ subsidy generates 0.7$ of additional private expenditure.

Regressions (1) and (4) allow us to calculate the elasticities of supply for researchers. $\ln((1+\beta)wL^{RS}) = \alpha_0 + \alpha_1\beta$; $\ln(L^{RS}) = \gamma_0 + \gamma_1\beta$. This implies, that $\frac{\frac{\partial \ln(L^{RS})}{\partial\beta}}{\frac{\partial \ln(w)}{\partial\beta}} = \varepsilon(L^{RS}, w) = \frac{\gamma_1}{\alpha_1-\gamma_1} = 1.19/(1.47-1.19) = 0.28$. This means that an increase of the wage of 1 percent controlling for the other variables will lead to 0.28 percent more researchers. The supply of researchers in the investigated period and countries in the short run is thus low and of similar magnitude as in the case of microstudies (Blundell and Macurdy 1999). This confirms the results by Goolsbee (1998), who finds that subsidies have strong wage effects because of the low wage elasticity of researchers supply. Our results therefore suggest that firms are able to react to changes in subsidization rate by employing additional researchers, however at the same time they have to pay for this increase in demand with higher wages.

[8]These values are calculated for average values of β and private expenditure/ subsidies to the research sector.

The regression results reported in table (3) give the long run estimation results. The first noticeable result is that the coefficient on beta is significant also in the long run. Subsidies to firms thus actually do generate additional research activity. Total spending increases by the same amount as the number of employees, so the increased subsidy in the long run has little effect on the wage rate. The supply of researchers is thus very elastic in the long run. The subsidy is in addition very ineffective in generating additional private funds, the coefficient is 0 in the long run.

Expenditure for university research, as well, contributes positively to research activity in the private sector. The coefficient has the same magnitude in the regression (4) of table 2, which indicates that there are little crowding-out effects. Higher expenditure for university research should feed into the supply of researchers only with significant lags, therefore we take this as evidence that on a contemporaneous level, there is a positive knowledge spillover from universities to private research. In the long run regression results, the effect on employment is the same as the effect in the short run. However, in the long run, university research seams to absorb some of the researchers' supply, which is reflected in the higher coefficient for total and private expenditure. University research thus has some wage effects, but it also has positive effects on researching in firms.

Basic research performed in the government sector (other than universities) is of no importance in the determination of research in the business sector.

4.4 The influence of macroeconomic variables on business research

The average tax rate in the economy (total tax revenues divided by GDP) has a significant negative influence on research activity, as well on employment as on total business research expenditure in the economy in the short run. Increasing average taxes by 1 percentage point will lead to roughly one percent less researchers in the short run. In the long run, firms seem to adjust to changing tax rates without changing their research intensity.

The openness of the economy contributes positively to research in the short run, however it is insignificant in the regression with expenditure as the explained variable. This corresponds to results by Coe and Helpman (1995), who find a positive technology spillover trough trade. Openness is not important in the long run, a finding in line with Kao et al. (1999), who do not find technological spillovers via trade with long-run estimation techniques.

The income per capita measured in constant US $ equivalent also has a significant positive impact on research in the business sector.[9] An increase of the income

[9] One might object that income per capita is an endogenous variable, which is influenced by the

per capita by 1 percent will lead to 1.7 percent more researchers. The coefficient in regression (4) is considerably higher which might indicates that expenditure for research fluctuate more strongly with the business cycle than employment.[10] In addition, in richer economies, the wages of researchers are higher so that the coefficient on spending is larger than the coefficient on employment or researchers (compare regressions 1 and 4). The long run regression results for income per capita are similar. In line with the new growth theory we believe that income per capita measures the profit opportunities of the business sector.

The long term interest rate is insignificant in regression 3 of table 2. Population size matters for aggregate research, in the short run changes in the population size are however only under-proportionally reflected in the number of researchers. In the long run the coefficient is significantly larger 1. There are thus scale economies in research with larger countries performing over-proportionally more research. This might indicate that in larger economies it is easier to appropriate the returns to research.

4.5 Human capital and business research

Changes in the human capital level of a country have no immediate effects on researcher employment, nor on spending for research. From an econometric point of view this can be explained by the fact that human capital levels are almost constant in time, qualification levels of societies change slowly. Therefore the fixed effect regression can not capture the importance of human capital since this effect is already captured by the fixed effect. The OLS regression results exploit the variation in the cross section and therefore allow to capture the importance of human capital. Human capital has a positive and significant influence on total research activity and on spending. If there is one percent more qualified people in the population, the number of researchers in the business sector will grow by roughly 0.5 percent.

5 Conclusions and Policy Implications

This paper investigated the role of several macroeconomic factors in explaining business sector research. The relevant macroeconomic factors were identified based on

number of researchers. However current research only has an effect on output through innovation with a certain time lag. The income stream generated by the researchers themselves is too small to significantly influence current GDP.

[10] Also included in this higher coefficient are movements of the PPP exchange rate calculation, since expenditure and GDP/L are measured in PPP 1991 \$ equivalent.

recent endogenous growth theory. In this literature, private enterprizes undertake research in order to innovate new products, which allow to temporarily monopolize markets and thereby generate true profits. The incentive to innovate depends on discounted future profits. The interest rate should therefore have a negative influence on current research. Profits also depend on the ability to implement innovations in the production process. On a macroeconomic level this is captured by the ratio of graduates in population. University research represents basic research, which is often the basis for applied firm research and should therefore be positively correlated with private research. Taxes reduce future profits and should lower the incentive to perform research. The openness of an economy indicates whether product markets are restrained to the national market or whether there are also profit opportunities abroad. Income per capita is also a measure of possible profit opportunities.

We took these factors as macroeconomic determinants of the business sector's demand for researchers. An additional factor which is possibly determining private research, are subsidies to firms. The new growth theory points out that in fact there are external effects of research leading to an undersupply of research. All industrial economies therefore subsidizes private research. An important question is whether these subsidies are indeed effective in the sense of actually leading to more research. Previous literature addressing this questions usually performed a regression of privately funded expenditure on public subsidies. This approach however is only of limited value since expenditure is not by itself a meaningful variable. We argue that the equilibrium number of researchers is actually the best proxy for actual research performed.

In our empirical model we therefore regressed the equilibrium number of researchers in the business sector on the average subsidization rate, average taxation, openness, outlays for universities, income per capita, graduates per capita, population, outlays for research in government institutes and the interest rate. In our sample of OECD countries, research is significantly explained by income per capita, graduates per capita and the population size. Outlays for higher education also impact significantly on private research. The average subsidization rate has a positive impact in the short run. In the long run it also has an effect, however it does not generate any additional private funds for research. There are no spill overs from government research institutes to private research. Human capital levels are insignificant in the short run. In the long run, however, differences in research activity are determined by human capital levels.

Several policy conclusions emerge from the analysis. While subsidizing firms indeed leads to increased research performed by the firms, the effect of the subsidy is much lower in the long run than in the short run. In addition, the subsidy does not generate any additional private funds in the long run. Basic research at universities is important for private business research. In the long run, the important factors for private research is the qualification of the population. It is by investing into human capital that the government will actually increase research and thereby long run growth.

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6 Appendix

6.1 Sources and definition of data

The data are taken from the OECD, Basic Science and Technology Statistics. We have an unbalanced panel of OECD countries with yearly observations from 1981 to 1997. Domestic R&D effort (expenditure and personnel) are divided into four sectors of performance: business enterprize, higher education, government, private non profit (PNP). We investigate the business enterprize sector. It includes all firms, organizations and institutions whose primary activity is the market production of goods and services (other than higher educations) for sale to the general public at an economically significant price, and the public enterprizes and PNP institutes mainly serving them.[11]

We define the average subsidization rate of the business enterprize sector as the ratio of subsidies to the business sector over business sector expenditure ($\beta = Berdg/Berdb$). In terms of our model $\beta = \frac{\beta * wL}{wL}$, that is we abstract from changing capital costs and assume that the capital costs are a constant fraction of total costs.

Our employment data cover all researchers in the business sector and all those persons providing direct services to the researchers (as secretaries, clerical staff). Data are expressed in full-time equivalents (FTE). One FTE may be thought of as one person-year.

Research spending in the government sector and in the higher education sector are equally taken from the OECD Basic Science and Technology Statistics. The government sector (**Goerd**) is composed of all departments, offices and other bodies which furnish but normally do not sell to the community those common services, other than higher education, which cannot otherwise be conveniently and economically provided and administer the state and the economic and social policy of the community. The higher education sector (**herd**) is composed of all universities, colleges of technology, and other institutes of post-secondary education, whatever their source of finance or legal status. It also includes all research institutes, experimental stations and clinics operating under the direct control of / administered by of associated with higher education establishments.

GDP data are taken from the OECD main economic indicators. The interest rate is taken from the IMF international financial statistics (IFS). Openness data are taken from Global Development Finance & World Development Indicators[12]. The

[11] For a description of the other three sectors see Summary of Frascati Manual, pages 16-17 (OEC 1994).

[12] See the world bank: http://www.worldbank.org/data

taxation rate is from the Government Financial Statistics of the IMF.

The data had to be cleaned in a number of ways. We linearly interpolated the employment data of researchers in the private sector if there was just one year missing. In case of two or more years missing, the data are coded as not available. However, by this method we only increased the number of observations by 29, from 169 to 198. In addition, we also performed the regressions with the non-interpolated data and the results did not change substantially.

Also the data on expenditure by the private sector were interpolated in case of 1 missing year, in case of more missing years, there was no interpolation.

Data on Human capital are taken from de la Fuente and Donémech (2000). We define human capital as the percentage of the population with a non-university tertiary + short university courses grade and/or a finished university education (**H3/L**.) de la Fuente and Doménech (2001) discuss the importance of their new human capital measure in explaining output growth in an augmented neoclassical growth model. They find that human capital plays a large role in explaining growth. The data on human capital are recorded only every five years. Therefore we linearly interpolated these data. This is not problematic since human capital levels of countries change very slowly. In five years, the change rarely exceeded 5 percentage points. In addition it is a common practice in the literature on human capital to interpolate data (Barrio-Castro et al. 2002).

The OECD publication **?**) also discusses the quality of the reported data. In some cases they report obvious mistakes, outliers, changes in statistical definitions, etc. We verified these particular reports and dropped outliers if the OECD suggested them to be wrong. Alternatively we performed statistical outlier analysis of the data without considered the OECD information. The regression results generated with the two alternative data sets do not differ much. We report the results of the regression with the data set that was corrected by hand based on the information of the OECD manual.

6.2 Statistical Tests

Let us start by looking at the error term of our model

$$u_{it} = \mu_i + \epsilon_{it} \tag{2}$$

The error term in equation 2 consists of an intercountry variation part and a purely random variation. One can compute the relative importance of the variation $\rho = \sigma_\mu^2/(\sigma_\mu^2 + \sigma_\epsilon^2)$.

In a first step, we want to investigate, whether we can actually pool our data. The standard test, the Chow (1960) test, however is only appropriate if $\rho = 0$ (Baltagi and Griffin 1984). More precisely the assumption underlying the Chow test is that $u_{it} \sim N(0, s^2 I_{NT})$, so a spherical error structure must be assumed. Monte Carlo experiments show that if the intercountry variation part is very large ($\rho = .9$), the Chow test will reject poolability of the data in 100 percent of the cases (Baltagi 1981). For our data set $\rho > .9$ holds. The appropriate test for poolability in the case of high ρ or the case of non-spherical errors is the test by Roy (1957) and Zellner (1962), see (Baltagi 2001). We implemented the Roy-Zellner test in STATA. The test statistic is given by $F = \frac{((RSS^* - RSS)/((N-1)*K))}{RSS/((T-K)*N))}$. However the results must be interpreted very carefully, since we need to estimate $N * K$ coefficients (N=16 countries, K=7 variables) for the unrestricted model. With only 200 observations, the fit of the unrestricted model will be almost perfect. The resulting residual sum of squares is very low compared to the restricted model, so that our test statistics will be very large and we almost automatically have to reject the H_0 of poolability because of the limited number of observations. We therefore assume that the data can be pooled.

The Hausman specification test (see Greene (2000),p.576) compares the coefficients of the random effect model and the fixed effect model. The H_0 of no systematic difference in the coefficients of the fixed effect vs random effect model could be rejected. This implies that the regressors and α_is are correlated, there is thus an endogeneity problem of the random effects estimation. We therefore estimate fixed effect regressions.

To get estimates of the long run response, we estimate a simple OLS model. However, to get consistent estimates of the standard errors, one needs to take into account the problem of heteroscedasticity, serial and contemporaneous correlation. In the simple OLS regressions, heteroscedasticity should be taken into account since the error variance will be different across individual countries. Beck and Katz (1995b) and Beck and Katz (1995a) criticize the widespread use of Parks (1967) methodology in the context of time-series-cross-section (TSCS) data to address these problems. Parks (1967) proposes a FGLS approach to the estimation of panel data, in which the errors are contemporaneously correlated, heteroscedastic and/or serially correlated. Beck and Katz (1995b) perform Monte-Carlo simulations with typical TSCS data and argue that Parks' approach yields standard errors that lead to extreme overconfidence, often underestimating the variability by 50% or more.

There are three possible solutions for heteroscedastic errors. (1) Heteroscedasticity might indicate a wrong model for the given data. So some data might be dropped. (2) One can get heteroscedasticity-corrected β estimates by means of GLS. This is done by transforming the original data by pre-multiplying them with an estimate of Ω^{-1} and then performing OLS. The estimates are asymptotically consistent and efficient. (3) Since the OLS estimator of β remains unbiased under heteroscedasticity, the only problem is the inefficiency of the estimator. One can therefore correct the estimate of the $var(\hat{\beta})$ according to the formula $var(\hat{\beta}) = (X'X)^{-1}\{X'\Omega X\}(X'X)^{-1}$. This is the normal formula for calculating the variance of the estimator, it simplifies to the usual OLS formula $\sigma^2(X'X)^{-1}$ if the Ω matrix is spherical (so diagonal, with constant variances).

Parks (1967) basically proposed approach (2), while Beck and Katz (1995b) argue that approach (3) is preferable. The argument relies on Monte-Carlo simulations and is thus an argument of small sample criteria vs. asymptotic theory. In addition, Parks (1967) approach is only feasible if $T \geq N$, which is not the case for our data. We therefore could not use this approach.

Beck and Katz (1995a) estimate with OLS, the standard errors are corrected with PCSE, so $var(\hat{\beta}) = (X'X)^{-1}\{X'\Omega X\}(X'X)^{-1}$. Since we do not know Ω, we have to estimate it. The panel structure of the data yields $\Omega = \Sigma \otimes I_T$. We therefore only need to estimate Σ, which is the $N \times N$ matrix of contemporaneous correlations of the errors. A natural estimate for Σ is $\hat{\Sigma} = T^{-1}\sum_{t=1}^{T} e_t e_t'$.

Thus, in line with Baltagi and Griffin (1984) and Beck and Katz (1995b), we estimate a simple OLS model to get the long run response of the variables. To get the appropriate standard errors, we employ PCSE method described above.

A variant of the Durbin Watson statistic developed by Bhargava, Franzini and Narendranathan (1983) indicates that there is autocorrelation in the errors. However the length of our sample is very small with between 8 and 15 observations, it is therefore debatable whether it is appropriate to correct for autocorrelation. We decided to take into account possible autocorrelation in the errors, doing so by variants of Prais and Winsten (1954). In addition we compared these results with the results of no autocorrelation correction, the results stayed qualitatively the same.