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IMPACT OF PUBLIC R&D FINANCING ON EMPLOYMENT

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ABSTRACT: This study analyses how public R&D financing impacts the labour demand of companies. To our knowledge, no previous studies have distinguished the impact on the firm's global and domestic employment. Our company-level panel data covers a period from 1997 to 2002. The statistical method employed in the study takes into account the possibility that receiving public support may be an endogenous factor. Our results suggest that public R&D financing increases both group-level and domestic R&D employment. We also analysed the impact of public R&D funding on other than R&D employment. According to our results, public funding does not have an effect on other than R&D employment. However, it is possible that these impacts exist in the longer run.

KEY WORDS: Public finance, R&D, employment, research and development, substitute, endogeneity.

ALI-YRKKÖ, Jyrki, **JULKISEN T&K-RAHOITUKSEN VAIKUTUS TYÖLLISYYTEEN.** Helsinki, ETLA, Elinkeinoelämän Tutkimuslaitos, The Research Institute of the Finnish Economy, 2005, 24 s. (Keskusteluaiheita, Discussion Papers; ISSN 0781-6847; no. 980).

TIIVISTELMÄ: Tässä tutkimuksessa tarkastellaan julkisen tutkimus- ja tuotekehitysrahoituksen vaikutuksia työllisyyteen. Aineistona käytetään yritystason paneliaineistoa vuosilta 1997-2002. Tutkimusmenetelmässä otetaan huomioon, että julkisen t&k-rahoituksen saaminen on mahdollisesti endogeeninen tekijä. Tulosten mukaan julkinen t&k-rahoitus lisää yritysten tuotekehityshenkilöstöä kotimaassa. Sen sijaan ulkomaiseen t&k-henkilöstön määrään julkisella t&k-rahoituksella ei ollut vaikutusta. Tutkimuksessa analysoitiin t&k-tukien vaikutuksia myös muuhun kuin t&k-henkilöstöön. Tulosten mukaan julkisella tuella ei ole vaikutusta tähän muuhun henkilöstön määrään konsernitasolla eikä myöskään kotimaan henkilöstöön. On kuitenkin mahdollista, että nämä vaikutukset näkyvät vasta pidemmällä aikavälillä. Tässä tutkimuksessa käytettävissä oleva aineisto ei mahdollistanut pitkällä viiveellä tulevien vaikutusten selvittämistä.

AVAINSANAT: julkinen rahoitus, t&k, tutkimus ja tuotekehitys, työllisyys, korvaavuus, endogeenisuus.

1 INTRODUCTION

According to the widely accepted view, the social return of R&D by firms is higher than the private return, thus unsurprisingly the public sector in almost all industrial countries tries to speed up technological change by using a variety of policy instruments, such as public R&D funding, national R&D laboratories and tax credits. However, the stimulation of the total R&D activity is hardly the ultimate goal of economic policy. Most of previous studies have ignored the fundamental issue whether public R&D funding finally leads to improved productivity, higher GDP, employment and welfare. This study focuses on the issue of how public R&D funding impacts employment.

Even though innovation is widely seen as an important source of growth, the impact of innovation on employment at the firm level remains unclear. One source of this uncertainty is the different nature of process and product innovations. Process innovations aim to improve productivity by enabling firms to achieve the same output with fewer resources. Thus, at least in the short run, process innovation may lead to job losses. In the long run, however, the improved competitiveness of the firm may stimulate demand leading to increases in output and employment (Harrison, Jaumandreu, Mairesse and Peters 2005). Thus, unsurprisingly the empirical evidence is mixed. While a number of studies have found a negative correlation between process innovations and employment (e.g. Antonucci and Pianta 2002), some other studies have reported a positive relationship (Blanchflower and Burgess 1998). Successful product innovations, in turn, likely lead to increases in employment. In practice, however, the distinction between process and product innovation is not always clear. New products potentially imply changes in the production process leading to productivity increases.

In sum, the results of existing studies concerning the relationship between innovation and employment vary. In this paper, we study a special kind of innovation namely firms' R&D funded by government. In light of the above, it is hard to assess *a priori* how the public R&D funding does affect employment.

In this study, we analyse the impact of public R&D funding on employment. To our knowledge, no previous studies have distinguished the impact on the firm's global employment and the impact on domestic employment. The stylised line of reasoning behind this issue is that the primary aim of technology policy is to promote the competitiveness of the national economy by technological means. Because the objective is to create domestic benefits, it is essential to differentiate between domestic and overseas impacts of the public R&D funding. Another new aspect of this study is that we also distinguish the impacts of public funding on R&D and non-R&D employment. However, our data does not allow us to distinguish non-R&D employment further (e.g. production employment, maintenance employment).

The remainder of the paper proceeds as follows. Section 2 includes relevant theoretical and empirical literature concerning the relationship between public and private R&D funding and the impacts on employment. Section 3 contains the description of the data. Section 4 gives an empirical analysis and results. Section 5 contains a summary and concluding remarks.

2 LITERATURE REVIEW

The main argument for public R&D funding is that the social return of R&D is higher than the private return, and thus from the perspective of the national economy firms under invest in R&D. Under-investment occurs because imperfect capital markets prevent companies from investing in all R&D projects with a positive net present value (NPV), or because the results of R&D spill over to other organisations.

Even though public R&D funding has several potential positive impacts, its real effect depends heavily on whether public R&D funding actually augments the total R&D expenditure of firms. Even though a number of empirical studies have addressed this issue, recent literature (Wallsten 2000 and Klette, Moen & Griliches 2000) has questioned the results of numerous previous studies with an argument that only a few studies have explicitly taken into account the potential endogeneity of public funding. Next, we shortly review the empirical literature where the endogeneity of public funding is controlled.

Wallsten (2000) examines the same SBIR programme as Lerner (1999) but points out the importance of taking into account the endogeneity of grants. Using the instrumental variable approach Wallsten reports an (almost) full crowding out effect. Busom (1999) analyses 154 Spanish firms of which roughly 50 per cent have received public subsidies. Due to the data limitations, Busom is unable to make an exact estimate of crowding out or complementary. However, her endogeneity-controlled analyses suggest that 41 companies spent more on R&D than they would have without the subsidy and 29 firms would have spent at least as much as in the case of no subsidy. Czarnitzki and Fier (2002) examine 210 German service firms. Applying a non-parametric matching approach, they find evidence that public funding has fostered the private innovation efforts of firms. By analysing more than 1,600 French firms, Duguet (2003) concludes that no significant substitution effect appears. Similar results have also been reported by Almus & Czarnitzki (2002), Hussinger (2003) and Gonzalez, Jaumandreu & Pazo (forthcoming). The evidence from Israel (Lach 2000) suggests that subsidies do not completely crowd out private R&D. Lehto (2000) analyses the effect of public funding on total R&D spending of Finnish plants and concludes that publicly funded R&D does not crowd out private R&D. Niininen & Toivanen (2000) apply a simultaneous equations approach and find evidence that Finnish firms with moderate cash flow add their own R&D expenditure as a response to a subsidy but when the cash flow is large enough, the positive relationship between subsidy and private R&D disappears. By examining Finnish firms in the period 1996-2002, Ali-Yrkkö (2004) concludes that receiving a positive decision to obtain public R&D funding increases privately financed R&D. The results also suggest that this additionality effect is bigger in large firms than in small firms.

To our knowledge, only a few studies have analysed the employment effect of public R&D funding. According to Lerner (1999), public R&D funding increases the labour demand of firms located in geographic areas with a high degree of venture-capital activity. Using the instrumental variable approach, Wallsten (2000) concludes that public funding has no effect on employment. Suetens (2002) reports the opposite result by analysing the impact of public R&D funding on R&D employment using a panel data of Flemish firms. Ebersberger (2004) utilised kernel-based matching and differences-in-differences techniques to analyse the labour demand effects of public R&D funding in Finland. The results suggest that during the R&D project the employment growth rates do not differ between subsidised and non-subsidised firms. However after the project, the average growth of employment is positive in subsidised firms but negative in non-subsidised firms. Thus, the results imply that in the longer run public R&D funding has a positive impact on employment.

There are two main caveats in the existing literature. *First*, employment impacts have been studied at the business group level without distinguishing domestic and overseas effects.. Foreign direct investment (FDI) statistics show that during the past decade overseas operations have substantially increased (World Investment Report 2004). Thus, it is essential to take into account that global impacts might differ from impacts domestically. *Second*, the existing evaluation studies have not distinguished between impacts on heterogeneous workers. It is possible that public R&D funding impacts differently on R&D employees and non-R&D employees (all other than R&D employees)[1]. Our purpose is to extend the existing public R&D funding literature by distinguishing the impact on the total (global) employment and domestic employment. Furthermore, we analyse separately the impact of public funding on R&D employment and non-R&D employment.

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[1] We define non-R&D employment as follows: Non-R&D employment = Total employment – R&D employment

3 DESCRIPTION OF THE DATA

Our data is a unique company-level dataset consisting of Finnish companies operating in different industries. Three separate data sources have been merged which make it possible to take into account a large set of explanatory variables. The information of both the total and the domestic employment is based on an investment survey conducted by The Confederation of Finnish Industry and Employers. Into this data, we have added the information of companies' financial statements provided by Balance Consulting and *Talouselämä* magazine. Finally, the data concerning the public R&D funding from the Finnish Technology Agency (Tekes) has been merged together with the two datasets mentioned.

In contrast to many previous studies, we are able to distinguish firms that 1) have applied for and obtained public funding, b) applied for and obtained only part of the amount for which they applied, c) applied for and been rejected, d) and firms that have not even applied for public funding. Thus, our dataset allows us to distinguish between firms that applied for funding but were denied and those that did not even apply.

With respect to the public funding variable, the choice between the subsidy *granted* and *actually paid* had to be made. While both alternatives include advantages and disadvantages, we follow the study by Meeusen & Janssens (2001) and use subsidies *granted*[2].

Our unbalanced database consists of 187 companies with various time series[3]. Companies with single observations available are excluded from the sample, thus our data includes only those companies with two or more annual observations. The next table (3.1) describes the data.

Our data consists of a pooled sample of companies over the six-year period from 1997 to 2002. On average, approximately 40% of the companies in our sample have received public funding. This share has remained rather stable during the period 1997-2002. Among the subsidised companies, during 1997-2002 the average share of public funding of the total R&D expenditure is 12%. In terms of this ratio, no trend can be observed from 1997 to 2002.

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[2] For the sake of simplicity, in the rest of the paper we have used public R&D funding, public funding and public funding granted as synonyms.

[3] To control the potential bias caused by outliers, in terms of net sales 5% of the biggest firms are excluded from the sample.

Table 3.1. Descriptive statistics

	Number of observa-tions	Mean	Median	Standard Deviation	Minimum	Maximum
Global R&D employ-ment	560	25.38	7	79.66	1	849
Global non-R&D em-ployment	557	424.39	229	525.36	1	3734
Domestic R&D em-ployment	560	21.45	7	56.54	1	586
Domestic non-R&D employment	492	358.29	213	401.12	1	2860
Total R&D, (EUR. mill.)	560	1.88	0.6	4.69	0.0075	49.88
Private R&D (EUR. mill.)	560	1.80	0.57	4.62	0.0075	49.88
Public funding (granted), (EUR. mill.)	560	0.096	0	0.32	0	5.06
Public funding (paid), (EUR. mill.)	560	0.075	0	0.2	0	2.04
Net Sales, (EUR mill.)	560	71.9	36.7	87.04	0.89	461.2
Wages/User cost	557	0.2	0.19	0.08	0.0025	0.58
Operating profit/Net sales	560	0.11	0.11	0.1	0	0.69

The comparison between the subsidised and non-subsidised (see appendix) suggests that in terms of net sales the subsidised are, on average, larger than the non-subsidised. Furthermore, the subsidised have more employees both at the global and the domestic level.

The existing literature indicates that foreign direct investment (FDI) in research and development (R&D) activities has increased (see e.g. Jungmittag, Meyer-Krahmer & Reger (1999). The annual breakdown of our sample shows that also in Finland overseas R&D operations have increased. In terms of R&D employees, on average 9% of firms have foreign R&D operations, which represent, on average, 24% of their total R&D employment. The share of R&D employees abroad of the total R&D employment has risen during the past years. While in 1998, the R&D employees abroad represented 17% of the total R&D employment of those companies with R&D employees abroad, in 2002 the share had risen to 32%. Evidently, foreign R&D is not a marginal operation mode in technology development.

4 EMPIRICAL ANALYSIS

Our estimation strategy proceeds as follows. First, we present OLS and instrumental-variable regressions of R&D employment on subsidies. Our data enables us to distinguish the impact on total and domestic R&D employment. We then extend the analysis to also cover other employees than those working in R&D. Hence, in these cases our dependent variables are the total non-R&D and domestic non-R&D employment.

4.1 Impact on R&D employment

We use a standard textbook model (see Bresson, Kramarz and Sevestre 1996) and consider an output constrained firm having a technological constraint which can be represented by a Cobb-Douglas production function and facing quadratic adjustment costs. Denoting by $E_t Z_{t+\tau}$ the expectation about $Z_{t+\tau}$, formed at time *t*, the path of firm's future employment is determined by minimising its expected costs (C_t)

$$C_t = E_t \sum_{\tau=0}^{\infty} \left(\frac{1}{1+r} \right)^{\tau} \left[c_{t+\tau} K_{t+\tau} + w_{t+\tau} L_{t+\tau} + \frac{d}{2} (\Delta L_{t+\tau})^2 + \frac{e}{2} (\Delta K_{t+\tau})^2 \right] \quad \forall t \qquad (1)$$

Subject to

$$g(K_{t+\tau}, L_{t+\tau}) = Q_{t+\tau} \qquad \forall \tau \qquad (2)$$

where L_t is the number of employees, K_t is the capital stock, Q_t is the production, *r* is the discount rate, c_t is the user cost of capital, w_t is the wage rate, *d* and *e* define the quadratic adjustment costs. Through Euler conditions and using the log approximation, the final dynamic employment equation added by an error term (v_t) is (for derivation, see Bresson, Kramarz and Sevestre 1996)

$$\log L_t = \alpha + \beta_1 \log L_{t-1} + \beta_2 \log Q_t + \beta_3 \log Q_{t-1} + \beta_4 \log \left(\frac{w}{c} \right)_t + \beta_5 \log \left(\frac{w}{c} \right)_{t-1} + v_t \quad (3)$$

where subscript *t* is time index, L_t is the number of employees, Q_t is production, w_t is wage per employee, c_t is user cost of capital and v_t is an error term. To capture the potential impact of public R&D funding, we include the lagged public R&D funding regressor ($PUBLIC_{t-1}$) in the equation (3) leading to:

$$\log L_t = \alpha + \beta_1 \log L_{t-1} + \beta_2 \log Q_t + \beta_3 \log Q_{t-1} +$$
$$\beta_4 \log\left(\frac{w}{c}\right)_t + \beta_5 \log\left(\frac{w}{c}\right)_{t-1} + \beta_6 PUBLIC_{t-1} + v_t \quad (4)$$

In equation (4) our special interest is focused on the coefficient β_6 measuring the relative response of employment to an absolute change of public R&D funding (in EUR millions). Thus, it describes the relative (percent change if the relative change is multiplied by 100) change of firms' employment if public R&D funding changes by EUR 1 million.

First, we estimate the model (4) by using the ordinary least-squares (OLS) method. This method, however, ignores the possibility that public funding is an endogenous variable. To control the potential endogeneity, an instrument variable (IV) method is used. An appropriate instrument correlates with the endogenous public funding variable but is not correlated with unobserved factors that have an impact on the dependent variable. According to Lichtenberg (1988) and Wallsten (2000), one ideal instrument is the value of funds that are potentially awardable to firm *i* in year *t*.

Following Wallsten (2000), for firms that have applied for public funding, we define the instrument, $BUDGET_{it}$, as follows:

$$BUDGET_{it} = AWARD_{at}^{i} \times \left(TEKESBUDGET_{at}\right), \quad (5)$$

where subscripts *i*, *a*, and *t* refers firm, industry and year, respectively. The dummy variable $AWARD_{at}^{i}$ gets a value 1 if the company *i* operating in industry *a* obtains public funding in year *t*. The variable $TEKESBUDGET_{at}$ is Tekes's budget for industry *a* in year *t*. Similarly, for a firm that applied in year *t* but was rejected, $BUDGET_{it}$ is defined as Tekes's budget for industry *a* in year *t*.

For firms that have never applied for Tekes-funding, the calculation of $BUDGET_{it}$ is more complicated. In this case, we have first calculated the probability of receiving funding if the firm had applied for it. The probability has been calculated by dividing the number of firms in industry *a* that received public funding by the total number of firms in industry *a* that applied. Then this probability, $p(AWARD_{at})$, has been multiplied by Tekes's budget ($TEKESBUDGET_{at}$) for industry *a* in year *t* (equation 3).

$$BUDGET_{it} = p(AWARD_{at}) \times \left(TEKESBUDGET_{at}\right) \quad (6)$$

The columns (a) and (b) in Table 4.1 report the results of the OLS and instrument variable (IV) regressions of equation (4) by using the total number of R&D employees as a dependent variable. In columns (c) and (d) we have replaced the dependent variable and used the number of domestic R&D employees as a dependent variable.

Table 4.1. Effects of public R&D funding on R&D employment

Dependent variable	log(Global R&D employment)		log(Domestic R&D employment)	
	(a) OLS	(b) IV	(c) OLS	(d) IV
log(Global R&D employment $_{t-1}$)	.9220567*** (.0274308)	.9063352*** .0232343		
log(Domestic R&D employment$_{t-1}$)			.9227595*** .0271935	.907516*** .0237877
(Public funding)$_{t-1}$	.1140658*** (.0251467)	.3695531* .2074826	.087303*** .0234919	.3325074* .1958537
Log(wages$_t$/user cost$_t$)	.1311986*** (.051654)	.1129809** (.0531724)	.1379752*** (.0513775)	.1203735** (.0517786)
Log(wages$_{t-1}$/user cost$_{t-1}$)	-.1162224** (.0493784)	-.0979935* (.0520032)	-.1289149*** (.0482916)	-.1112445** (.0500082)
Log(Production$_t$)	.0083795 (.0803107)	-.0123865 (.0762868)	-.0314135 (.0755972)	-.0505165 (.0721074)
Log(Production$_{t-1}$)	.0444607 (.0778023)	.0594624 (.0734954)	.0768709 (.0736483)	.0902483 (.0699681)
Constant + Industry dummies + Year dummies				
Number of observations	560	560	560	560
F-test (joint)	721.69	7.32	907.2	7.31
P-value	<0.001	<0.001	<0.001	<0.001
R^2	0.95		0.95	

NOTES: Heteroscedasticy-corrected standard errors in parentheses.
Instruments (column b): Year dummies, industry dummies, BUDGET(t-1), Total R&D employment (t-1), wages/user cost (t), wages/user cost (t-1), Production (t), Production (t-1).
Instruments (column d): Year dummies, industry dummies, BUDGET(t-1), Domestic R&D employment (t-1), wages/user cost (t), wages/user cost (t-1), Production (t), Production (t-1).
F-test = tests the hypothesis that all coefficients excluding constant are zero.
*** = significant at the 1% level
** = significant at the 5% level
* = significant at the 10% level

According to the OLS estimation (column *a* in Table 4.1), the coefficient for the public funding in time *t-1* is positive and statistically significant at the 1% level suggesting the positive correlation between public R&D funding and the total R&D employment. The coefficient of the wage/user cost ratio in time *t* is surprisingly positive and statistically significant. However, the coefficient of the lagged wage/user cost is negative and statistically significant. Some previous studies (e.g. Bresson *et. al*. 1992) have also reported opposite signs of the coefficient of wage/user cost variable in different periods[4].

These OLS estimates, however, might be biased because of the presence of the endogeneity of public funding variable (see Wallsten 2000). To control the potential endogeneity of public funding, IV estimation was carried out (column *b*)[5]. Again, the public funding has a positive and statistically significant impact on labour demand. Hence in contrast to Wallsten's study (2000), controlling endogeneity does not change the positive impact of public funding.

These two estimations (columns *a* and *b*), however, do not take into account the possibility that firms have increased their R&D employment abroad instead of domestically. From the perspective of the national economic policy, decision-makers are primarily interested in impacts on the domestic economy. To address this concern, we have re-estimated the models by using domestic R&D employment as a dependent variable (columns *c* and *d*). The results of these estimations suggest that there is a positive correlation between public R&D funding and domestic R&D employment. To calculate the economic magnitude of our results (column *d*), we multiply the coefficient of public funding (0.3325) by the mean of R&D employment (21.45). Thus, domestic R&D employment increases by 7 employees when a company obtains EUR 1 million public funding. Respectively, the global (total) R&D employment increases by 9 employees when a company obtains EUR 1 million public funding (column *b)*. In sum, our results indicate that public R&D funding impacts positively both domestic and global R&D employment[6]. We also used a generalised method of moments (GMM) estimator (see Blundell & Bond 1998) to estimate equation 4 (see Robustness tests). However, in constructing first differences and instruments, we lose several observations.

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4 We also estimated equations without the public funding regressor (see appendix). According to the results of these estimations, the coefficients of wage/user cost and production were very similar as in equations with public funding (Tables 4.1 and 4.2).

5 Our first-stage estimation (see Appendix) suggests that $Budget$ is positively and statistically significantly correlated with $public\ funding$.

6 We also estimated equations by using foreign R&D employment as the dependent variable (not reported). The results of these estimations suggest that public funding does not correlate statistically significantly with foreign R&D employment.

4.2 Impact on non-R&D employment

Next, we ask how public R&D funding impacts other than R&D employment. If R&D employees succeed in developing new products or increasing the competitiveness of firms, presumably also employment other than only R&D staff will increase. Product innovations are more likely to lead to increases in employment but also process innovations potentially lead to employment increases in the long run. However, in some cases the short-term impacts of process innovations probably are negative. The previous literature (e.g. Bresson, Kramarz and Sevestre 1992) suggests that an aggregate labour demand model can lead to erroneous conclusions if the employment of a given category of employees decreases while it increases for others.

Table 4.2. The impact of public funding on non-R&D employment

Dependent variable:	log(global non-R&D employment $_t$)		log(domestic non-R&D employment $_t$)	
	OLS (a)	IV (b)	OLS (c)	IV (d)
log(other employment $_{t-1}$)	.8257497*** .0885548	.8251021*** (.0691643)		
log(domestic other employment $_{t-1}$)			.8310909*** (.0723669)	.8286044*** (.07549)
(Public funding)$_{t-1}$	.0168382 (.0275636)	.1794575 (.1778181)	-.0034888 (.0293043)	.198695 (.1605382)
Log(wages$_t$/user cost$_t$)	.0504464 (.0447735)	.0368952 (.0564625)	.1177119** (.0448189)	.0998554** (.0464304)
Log(wages$_{t-1}$/user cost$_{t-1}$)	.0272973 (.0667947)	.0375806 (.0626664)	-.073808 (.0518724)	-.0595196 (.0516451)
Log(Production$_t$)	.2929509* (.1537272)	.2800133** (.1362021)	.1939886** (.0923247)	.1767746** (.0875658)
Log(Production$_{t-1}$)	-.2371136* (.1399956)	-.2311849* (.1374336)	-.1181316 (.0774028)	-.1101425 (.074387)
Constant + Industry dummies + Year dummies				
Number of observations	554	554	456	456
F-test (joint)	653.2	6.49	484.63	5.25
P-value	<0.001	<0.001	<0.001	<0.001
R^2	0.94		0.91	

NOTES: Heteroscedasticy-corrected standard errors in parentheses.

Instruments: Column c: Year dummies, Industry dummies, BUDGET(t-1), Global other than R&D employment (t-1), wages/user cost (t), wages/user cost (t-1), Production (t), Production (t-1)

Column d: Year dummies, Industry dummies, BUDGET(t-1), Domestic other than R&D employment(t-1), wages/user cost (t), wages/user cost (t-1), Production(t), Production(t-1)

F-test = tests the hypothesis that all coefficients excluding constant are zero.

*** = significant at the 1% level

** = significant at the 5% level

* = significant at the 10% level

To analyse the effect on the total employment, we use other than R&D employment (non-R&D employment) as a dependent variable. We first estimate the equation (4) by OLS and IV using global non-R&D employment as a dependent variable and then re-estimate equations by using domestic non-R&D employment as the dependent variable. The results are presented in Table 4.2.

The first point worth noticing is that in terms of public R&D funding all methods yield quite similar results. We find no evidence that public funding increases non-R&D employment. All the coefficients of public R&D funding in Table 4.2 are statistically insignificant indicating that public R&D funding has no effect on other than R&D employment. However, it is possible that the impact of public funding on other than R&D employment occurs in the longer run.

In sum, our estimations suggest that public funding has a positive and statistically significant impact on R&D employment. However, we found no evidence that public funding impacts other than R&D employment (e.g. employees in production).

4.3 Robustness tests

Next, we perform a number of robustness tests. To save space we do not report these tests in detail.

Robustness test 1:

Does the problem of weak instruments cause a bias in our results? To address this question, we re-estimate our models by using an additional instrument. While the correlation between $BUDGET_{it}$ and $PUBLIC_{it}$ is 0.22 (see appendix), the correlation between $PUBLIC_{it}$ and $APPLIED_{it}$ (the amount of public funding that a company has applied for) is as high as 0.979. However, it is hard to see why $APPLIED_{it}$ should correlate with the unobserved determinants of private R&D, conditional on the actual R&D funding received. We re-ran our models using this additional instrument. According to the results of these new regressions, our major result that public R&D funding increases domestic R&D employment holds

Robustness test 2:

Do our results change if we take into account firm-specific effects? To test this concern, in dynamic models it is necessary to use a generalised method of moments (GMM) estimator. However, by taking first differences and constructing an appropriate instrument set, we lose several cross-sections. We follow Blundell & Bond (1998) and use both lagged level and differenced variables as instruments. The results of these new regressions show that our basic results hold (see Appendix). *First*, when domestic R&D employment is used as the dependent variable, the coefficient of public R&D funding remains positive and statistically significant (*t*-value 3.01). *Second*, public R&D funding does not have a statistically significant impact on non-R&D employment (*t*-value 0.92).

Robustness test 3:

To test whether the public R&D funding impacts non-R&D employment in the longer run, we re-ran our models three times by lagging the public funding regressor two, three and four years, respectively. The results of these new estimations support our previous estimations that public R&D funding does not have a statistically significant effect on non-R&D employment.

Robustness test 4:

To what extent are our results specific to the period on which we focus? To address this question, we run our models separately for the period 1997-2000 and 2001-2002. The results of these new regressions indicate the following: *First*, public R&D funding has no statistically significant impact on other than R&D employment either in the period 1997-2000 or in 2001-2002. *Second*, public funding increases domestic R&D employment in the period 2001-2002 (*t*-value 2.3) but not in 1997-2000 (*t*-value -1.4). Even though our sample is too short to reach a definite conclusion, the result potentially indicates that the impact of public R&D funding is different during economic booms and recessions. The wage inflation of R&D employees is one interpretation of the empirical result that during the economic boom in 1997-2000, the public funding did not increase employment. Thus during the economic boom in 1997-2000, a significant fraction of increased R&D spending potentially went into higher wages of R&D employees (as proposed by Goolsbee 1998) instead of the number of R&D employees. However, during the recession in 2001-2002, the public funding increased the number of domestic R&D employees.

5 CONCLUSIONS

This study analysed the impact of public R&D funding on employment by using firm level data on Finnish companies during 1997-2002. This paper contributed to the existing literature in two ways. *First*, we distinguished between the impacts of public funding on firm's total and domestic employment. Due to the increasing overseas activity both in production and R&D operations, it is essential to distinguish between global and domestic impacts. *Second*, we also estimated separately the impact on R&D and other than R&D employment.

Our results suggest that public R&D funding has a positive and economically significant impact on domestic R&D employment. From the perspective of national economic policy, it is important that the policy has positively impacts particularly domestically.

We also examined whether the public funding impacts other than R&D employment. However, we found no evidence that public funding affects non-R&D employment in domestically. This result did not change when we examined the impacts on the other employment at the group's global level.

Our results have several important policy implications. *First*, our results do not support the view that the only effect of public R&D financing is to raise the wages of researchers (Goolsbee 1998). In contrast, our results show that public R&D funding does have a positive impact on the R&D labour demand. However, according to our results during economic booms the impact of public funding on R&D employment is potentially different than during recessions. While our estimations suggest that during the economic slowdown (2001-2002) public funding increased the number of R&D employees, we do not observe a similar relationship during the economic boom in 1997-2000. *Second*, we found no evidence that at least in the short run public R&D funding increases the labour demand of other than R&D employment. This is an important result because rather than the increased innovativeness, the ultimate goal of economic policy is, for example, improved competitiveness, increased exports, increased employment or finally improved welfare.

Due to data limitations, there are several topics left for future research. First, our data does not allow us to separate public funding directed at process innovations and product innovations. Thus, our estimates capture an average relationship that may hide impact differences between these two types of innovations. Second, to analyse more rigorously the impact of public funding on non-R&D employment data with a longer time series is needed. The delay from R&D to pilot production and from pilot production to full production potentially takes several years and this should be taken into account in future studies. Third, the widely accepted major rationale for public R&D is the spill over effect, that is, the output of an R&D project spills over to other organisations. To examine the aggregate impact of public funding on employment, one should also take into account the employment effects caused by spillovers.

6 APPENDIX

Data appendix

The data related to financial reports came from Balance Consulting Ltd. and *Talouselämä* magazine's top 500 database. All variables are deflated using the GDP price index (2000=100).

Employment

The total (worldwide) number of employees of the firm as reported in the investment survey by the Confederation of Finnish Industry and Employers or in the database of Balance Consulting Ltd.

Domestic employment

The total number of employees of the firm in Finland as reported in the investment survey by the Confederation of Finnish Industry and Employers.

R&D employment

The total number of R&D employees of the firm as reported in the investment survey by the Confederation of Finnish Industry and Employers.

Domestic R&D employment

The number of R&D employees of the firm in Finland as reported in the investment survey by the Confederation of Finnish Industry and Employers.

Wages

Total wages (including social expenses) came directly from the income statement of the firm. Wage per employee has been calculated by dividing total wages by total employment.

User cost

To calculate the firm-level user cost of capital c_{it} we use the following equation (Koskenkylä 1985 and Pyyhtiä 1991):

$$c_{it} = \frac{p_t^I (r_{it} - E[\dot{p}_t^I] + \delta^A)(1 - \tau_t \frac{\alpha}{r_{it} + \alpha})}{p_t^o (1 - \tau_t)} \qquad ,$$

where i=1,...,N and t=1,...,T, and

p_t^I = price of investment

$E[\dot{p}_t^I]$ = Expected change in the prices of capital goods. Calculated by taking an average of the inflation rate of capital goods (Source: Statistics Finland) during the past five years.

r_{it} = The interest rate. The firm-level interest rate has been calculated by dividing interest rate expenditure by interest-bearing debt.

δ^A = Economic rate of depreciation of the capital stock. The industry-level depreciation rate has been calculated from our sample by adding up the depreciation of all companies and dividing it by the sum of fixed assets.

τ_t = Corporate tax rate.

α = The maximum rate of depreciation in taxation on the total un-depreciated capital stock.

p_t^o = Price of output (Source: Statistics Finland)

Total R&D expenditure

Total R&D expenditure (irrespective of financing) of the firm as reported in the investment survey by the Confederation of Finnish Industry and Employers.

Public R&D funding

This data came from the National Technology Agency (Tekes). Public funding includes R&D loans and subsidies.

Privately financed R&D

Privately financed R&D has been calculated by subtracting public R&D funding from the total R&D expenditure.

Sales

Net sales came directly from the income statement of the firm.

Table A.1. Descriptive statistics (Means and two-tailed *t*-tests for means) by subsidised and non-subsidised

	Firms without subsidy at *t*	Firms with subsidy at *t*	*t*-value	*p*-value
Global R&D employment	21.6	30.9	-1.358	0.175
Global other than R&D employment	314.2	583.4	-6.14	<0.0001
Domestic R&D employ-ment	18.1	26.4	-1.7	0.089
Domestic other than R&D employment	271.1	490	-6.14	<0.0001
Total R&D, (EUR. mill.)	1.45	2.5	2.6	0.01
Net Sales, EUR mill.	55.71	95.47	-5.45	<0.0001
Wages/User cost	0.205	0.204	0.149	0.88
Operating profit/Net sales	0.12	0.105	2.07	0.039

Table A.2. Correlation matrix

	Total R&D expendi-ture	R&D emplo-yment	Domestic R&D emplo-yment	Other than R&D employ-ment	Domestic other than R&D employ-ment	Net sales	Wage/ user cost	Public funding (granted)	Budget	Public funding (applied for)
Total R&D expendi-ture	1.0000									
R&D employment	0.8529	1.0000								
Domestic R&D employment	0.8645	0.9222	1.0000							
Other than R&D employment	0.1487	0.1511	0.1554	1.0000						
Domestic other than R&D employment	0.1423	0.1171	0.1250	0.8813	1.0000					
Net sales	0.1600	0.1708	0.1482	0.8168	0.7501	1.0000				
Wage/user cost	0.0083	-0.0006	0.0042	-0.0801	-0.0423	0.0800	1.0000			
Public funding	0.2274	0.1672	0.1478	0.1392	0.1410	0.1516	-0.0669	1.0000		
Budget	0.0861	0.0609	0.0560	-0.1396	-0.1410	-0.2120	-0.0540	0.2285	1.0000	
Public funding applied for	0.2303	0.1851	0.1575	0.1603	0.1635	0.1726	-0.0618	0.9793	0.2344	1.000

Table A.3. First-stage regressions (IV regressions in Table 4.1)

Dependent variable	Column *b* in Table 4.1 Public funding (t-1)	Column *d* in Table 4.1 Public funding (t-1)
log(Global R&D employment $_{t-1}$)	.048582*** .0129804	
log(Domestic R&D employment$_{t-1}$)		0488473*** (.013121)
(Budget)$_{t-1}$	.015649*** (.0022426)	.0156322*** (.0022438)
Log(wages$_t$/user cost$_t$)	.0632884 (.0426067)	.0637233 (.0426065)
Log(wages$_{t-1}$/user cost$_{t-1}$)	-.0727046* (.0428565)	-.0732252* (.0428696)
Log(Sales$_t$)	.1033919 (.0691468)	.1007122 (.0691616)
Log(Sales$_{t-1}$)	-.0749687 (.0699512)	-.0715914 (.0699115)
Constant + Industry dummies + Year dummies		
Number of observations	560	560
F-test (joint)	7.32	7.31
P-value	<0.001	<0.001
R^2	0.21	0.21

Table A.4. Generalised Method of Moments (GMM) estimations

	GMM	GMM
Dependent variable	(a) log (domestic other than R&D employment)$_t$	(b) log (domestic R&D employment)$_t$
log(domestic other than R&D employment $_{t-1}$)	0.709594*** (0.1874)	
log(domestic R&D employment $_{t-1}$)		0.973984*** (0.04172)
(Public funding)$_{t-1}$	0.0356170 (0.03863)	0.111782*** (0.03718)
Log(wages$_t$/user cost$_t$)	0.279517 (0.2362)	0.349629 (0.3118)
Log(wages$_{t-1}$/user cost$_{t-1}$)	-0.139557 (0.1828)	-0.471645* (0.2803)
Log(Sales$_t$)	0.266184 (0.1874)	-0.117083 (0.3445)
Log(Sales$_{t-1}$)	-0.205643 (0.2159)	0.143528 (0.3526)
Constant + Year dummies		
Number of observations	264	321
Wald (joint)	472.7	1590.0
Sargan [p-value]	22.43 [0.263]	18.97 [0.459]
AR(1) test	-1.776	-2.051
AR(2) test	-0.7301	-1.568

Notes:

i) The Wald (joint) statistic is a test of the joint significance of the independent variables.

ii) Sargan is a test of the over-identifying restrictions, asymptotically distributes as χ^2 under the null of instrument validity.

iii) AR(1) and AR(2) are tests for first-order and second-order serial correlation in the first-differenced residuals, asymptotically distributed as N(0.1) under the null of no serial correlation.

iv) The GMM estimates reported are all one step estimates.

v) Public funding variable has been instrumented by BUDGET.

vi) The results are obtained using DPD for Ox (see Doornik, Arellano and Bond (2001)).

Table A.5. Employment estimations without public funding regressor

Dependent variable	log(Global R&D employment) OLS	log(Domestic R&D employment) OLS	log(global non-R&D employment $_t$) OLS	log(domestic non-R&D employment $_t$) OLS
log(Global R&D employment $_{t-1}$)	.9290758*** (.0269523)			
log(Domestic R&D employment$_{t-1}$)		.9281869*** (.0265845)		
log(global non-R&D employment $_{t-1}$)			.8258167*** (.0884942)	
log(domestic non-R&D employment $_{t-1}$)				.831048*** (.07228179
Log(wages$_t$/user cost$_t$)	.1393322*** (.051801)	.1442422*** (.0515858)	.0518496 (.0439196)	.1174038*** (.0448582)
Log(wages$_{t-1}$/user cost$_{t-1}$)	-.1243609** (.049107)	-.1352063*** (.0482129)	.0262326 (.0660318)	-.0735615 (.0521906)
Log(Production$_t$)	.0176508 (.0826674)	-.024612 (.0773755)	.2942905* (.1547525)	.1936916** (.0915823)
Log(Production$_{t-1}$)	.0377629 (.0801669)	.072108 (.075459)	-.2377275* (.1405254)	-.1179938 (.0769955)
Constant + Industry dummies + Year dummies				
Number of observations	560	560	554	456
F-test (joint)	737.22	888.21	661.47	491.72
P-value	<0.001	<0.001	<0.001	<0.001
R^2	0.94	0.95	0.94	0.91

NOTES: Heteroscedasticy-corrected standard errors in parentheses.
F-test = tests the hypothesis that all coefficients excluding constant are zero.
*** = significant at the 1% level
** = significant at the 5% level
* = significant at the 10% level

Table A.7. The role of foreign R&D by year

Year	Number of firms	Number of firms with foreign R&D employment>0	Mean (Foreign R&D employment/Global R&D employment*100) for firms with foreign R&D employment >0
1998	81	5	16.9%
1999	108	7	19.7%
2000	119	11	27.2%
2001	130	11	25.6%
2002	122	16	31.9%

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