The EU Framework Programs: Are they worth doing?

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Abstract:

Using CIS data from the Netherlands, Germany and France we test whether EU Framework programs do have effects on their participants' R&D input and innovative output. From our Heckman selection equations, we conclude that the FPs attract the "elite" of European innovators. The question is whether, after correction for self-selection, the programs have positive effects on innovative behaviour. This is hard to test meaningfully among large firms as EU funding is likely to cover only a minor share of their innovative activities. Analysing changes in R&D input we find that smaller firms increase their R&D input quite substantially after entering an EU FP program.

Estimating equations that explain sales of innovative products, we find that firms that collaborate on R&D with clients, suppliers, competitors or public research institutes do not have increased sales of innovative products. We try to provide explanations for this counter-intuitive finding. Moreover, participation in an EU FP neither increases sales of innovative products. This result holds after numerous robustness checks.

We argue that our insignificant outcomes do not necessarily imply that the FP programs are worthless. There is independent evidence that innovative projects funded by the EU FPs do, on average, involve more technical and scientific risks, they are more complex, and involve longer time horizons. Obviously, they are farer from market introduction which is not surprising, given the regulatory demand that EU FPs should be "pre-competitive". Against this background, we cannot exclude the possibility that an insignificant coefficient of FP participation in our equation on innovative output may still have a positive meaning.

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I Introduction: The problem

The Framework Programs (FPs) of the European Union consume substantial amounts of public money, and they involve a heavy bureaucratic burden for the participants and for the Commission. It is therefore legitimate to raise the question: is all that worth doing? In this paper, we address two questions. First, do the subsidies from the FPs lead to additional R&D efforts among the participants? And second, are R&D inputs, as initiated by the Framework Programs, used more efficiently in producing innovative outputs?

In this paper, we use data from the *Community Innovation Survey* (*CIS*) that directly measures innovation output. The CIS is asking firms whether, during the past three years, they have developed and introduced technologically new products that were either 'new to the firm' (i.e. already known in their market) or even 'new to the market'. While the former is an indicator of imitation, the latter covers what we might consider 'true' innovations, defining an innovation as the market introduction of a new product. For the purpose of this study, we are mainly interested in innovation, rather than imitation. By dividing a firm's innovative sales by its total sales (or some other measure of firm size, e.g. employees), we obtain a measure of the output side of the innovative process. Relating a firm's innovative input (R&D) to its innovative 'output' (sales of innovative products) we can say something about the efficiency of the innovative process. A number of factors can influence efficiency, e.g. firm size, technological opportunities in the firm's sector of principal activity or possibilities for appropriation of innovation benefits. Below, we shall discuss such factors in more detail.

In order to test whether the FPs have a positive impact on innovation, it is not sufficient to show that program participants innovate more than non participants. We need to control for the well-known Heckman self-selection bias. We therefore estimate a selection equation that informs us about typical properties of firms that participate in FPs. In other words, we test whether firms that participate in an FP are more innovative than are non-participants, correcting for the fact that participants may be more innovative by reasons other than participation in an FP.

Besides testing whether participants have higher innovative output, we also apply some refinements. By means of interaction dummies, we evaluate whether certain types of participants (e.g. smaller or larger firms; more or less R&D intensive firms or firms from certain sectors) do or do not achieve more innovative output if they participate in an FP.

A priori, we expect firms that self-select themselves into FPs to be more innovative. This would result in an overestimation of our parameters for the properties that drive innovation which we correct by means of a Heckman term for self-selection into the FPs. In explaining innovative output, we consider the following factors:

- A firm's R&D intensity: Firms with intensive R&D efforts are likely to have a greater "absorptive capacity" and can therefore learn more quickly from others, and, in particular, from their partners in an FP.
- We explore whether application of the famous Pavitt taxonomy[1] could give interesting distinctions. For example, "science based" innovators could take greater advantage from FP consortia with public research institutes (notably universities), while "specialized suppliers" might benefit more from participating in consortia that bring together clients and suppliers.
- By comparing Greek data to those of Germany, France and the Netherlands, we hope to get a hint about whether PF participants from less-developed parts of the EU can benefit from "catching up" effects from collaboration with firms from richer countries.
- Firms that have more generally a high propensity to collaborate on innovation might have more benefits from an FP, as they have experience in successfully managing collaborative R&D.

In conclusion, we might achieve a double result: First, information about whether, in general, participants in FP's perform better (not because they are better innovators but) because they participate in an FP. Second (irrespective of whether the first question is answered by yes or no), we can find out which type of firm is particularly successful (or fails) to take advantage from participation in an FP.

The reader should note that the critical factors mentioned above are all measured at the firm level in the CIS. We estimate equations that explain a firm’s innovativeness and add a dummy (or cross-dummies) for participation in Framework Programs.

II A survey of the empirical literature

There is a wealth of literature on the economic benefits of subsidies, such as EU Framework Programs, for R&D, either collaborative or not. In mainstream economics, these subsidies are suspect but tolerated on the grounds that profit maximizing firms underinvest in R&D and there are positive externalities to R&D, such as spillovers to other industries and the acquisition of knowledge in the economy. A common criticism is that government subsidies ‘crowd out’ private investment in R&D (e.g. Wallsten, 2000).

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[1] For a recent update of the famous Pavitt taxonomy (originally formulated in a 1984 *Research Policy* paper), see J. Tidd, J. Bessant & K. Pavitt: *Managing Innovation*, Chichester: Wiley, 2005 (3rd edition).

In this paper we are predominantly interested in effects of EU Framework Programs, which are essentially subsidy programs for cooperative R&D, on innovative output. Earlier research tended to focus on the consequences of subsidies for R&D expenses (David et al, 2000) and on the relation between R&D collaboration and innovative output, besides research on the determinants of R&D collaboration.

All studies investigating effects of R&D subsidies face a similar selection issue. Enterprises that receive subsidies for (collaborative) R&D could be different than enterprises that do not. Furthermore, based on these differences, they might be more likely to be granted subsidies and thus, select themselves into the subsidy program. All of this causes biases in estimating the effect of subsidy programs. This selection bias problem has been documented in the literature (e.g. David et al, 2000; Busom, 2000) to some extent. In more recent research, this selection bias problem is typically dealt with, using a Heckman selection model or a matching approach.

Research investigating the impact of R&D on innovation is widespread. With French CIS data Mairesse & Mohnen (2004) find that R&D expenditure per employee is positively correlated with all measures of innovation activity. With the same data source (CIS) for the Netherlands, in a longitudinal analysis, Belderbos et al (2004), find proof that R&D cooperation, in particular with universities, has a positive effect on growth of new to the market sales per employee. In contrast to these findings, Negassi (2004) found only a minor role for R&D collaboration in achieving commercial success of innovations with French CIS data as did Brouwer & Kleinknecht (1996) with Dutch CIS data.

A related strand of literature investigates the relation between receiving subsidies for R&D and subsequent private R&D expenditure. With CIS data for Sweden, Lööf and Heshmati (2005) find that public funds contribute to an increase in the total R&D efforts in Sweden, but the only beneficiaries are small manufacturing and service firms. The results rejected the crowding out hypothesis but they did support the hypothesis on the additive effect of public R&D support on private research expenditure, among small firms with 10-50 employees. With CIS3 and CIS4 data for Germany and Flanders, Aerts and Schmidt (2006) reject the crowding out hypothesis both when using a matching approach and when using a combination of the matching procedure and the difference-in-difference method, i.e. conditional difference-indifference using the two cross-sections of CIS3 and CIS4. Their conclusion is that funded firms are significantly more R&D active than non-funded firms.

III Data requirements

In recent years, the Community Innovation Survey (CIS) allowed for numerous innovation studies, which greatly enhanced the state of our knowledge. The core questionnaire of the CIS (as defined by Eurostat) includes a direct 'yes'/'no' question on whether a firm participated in Framework Programs. Unfortunately, the relevant question makes no distinction between FP 4 (1994-98) and FP 5 (1998-2002). Nor does it make a distinction by type of program. We believe, nonetheless, we can still make an appropriate test. Eurostat is undertaking efforts to make CIS micro data available for analyses. Unfortunately, the micro data by Eurostat cannot yet be linked at the firm level between subsequent CIS surveys. Such a linking would be most desirable, as it creates panel data that would greatly increase the value of the CIS for research purposes.

For the purpose of this study, we were able to link CIS 3 (covering year 2000) with CIS 4 (covering year 2004) in three countries[2]. This allows for introduction of a time lag between sales of innovative products and our exogenous variables (R&D input, R&D collaboration, participation in FPs, etc.). In order to investigate the selection mechanisms underlying participation in Framework Programmes, we start with an analysis of typical properties of firms that participate in FPs.

IV Properties of firms that participate in Framework Programs

Firms that have no (or little) innovation activities would probably not pass through the tough selection procedures of the EU. A priori, we expect that participants should belong to the 'elite' of innovating firms in Europe. We expect them to have a substantial innovation function, exceeding the average standards of their sector of principal activity; they might be experienced in R&D collaboration, and one might expect them to be large and oriented towards international operations.

In the following, we take data from CIS 4 (covering year 2004) in order to test what are the typical properties of FP participants. As we have a binary variable (participation in FPs: yes/no?), we can use the simplest version of the logit model. The table 1 summarizes our outcomes.

Other than expected, participants in FPs do not generally have above-average probabilities of engaging into R&D collaboration, compared to non-participants. They do have higher probabilities of collaborating with clients, but not with suppliers (with the exception of France). In Germany, FP participants also have higher probabilities of collaborating with competitors but this does not hold for the Netherlands, and it holds weakly for

[2] For Greece, we had access to both CIS3 and CIS4 waves, but apparently none of the firms ‘survived’ from the CIS3 to the CIS4 survey.

France. It comes as no surprise that FP participants do collaborate more often with universities and public research institutes in all three countries, as Framework Programs involve (and more or less require) collaboration with such institutes. Summarizing, we can say that participants in FPs tend to be more than average networked, although they are less networked than we had a priori expected.

As expected, larger firms have higher probabilities of being involved in a Framework Program. While smaller innovators have the well-known advantages of smaller bureaucracies, shorter communication lines and higher flexibility, they have chronic problems of lacking resources (finance, knowledge etc.) and of missing scale economies (Tidd et al. 2003). Moreover, larger firms tend to have market power and monopoly profits that are helpful in launching risky products or in financing large R&D facilities over longer periods. It is no surprise that FP participants have R&D intensities above the average of in their sector of principal activities. Moreover, FP participants have a stronger international orientation, which allows spreading the (sunk) costs of R&D over larger markets.

The finding that FP participants are also more likely to hold patents supports the impression that they belong to the 'elite' of innovators, although patents are not necessarily a reliable indicator of innovation. Confronting innovative output to patenting activities, Brouwer & Kleinknecht (1999) conclude that firms that collaborate on R&D have higher propensities of applying for patent protection. The most likely explanation is that they do not trust their partners. Before engaging into R&D collaboration, they want to protect their most precious knowledge.[3] This argument will also become relevant below. Hence, our finding (to be reported below) that FP participants have higher numbers of patents does not necessarily prove that they are more innovative.

[3] Brouwer, E. & A. Kleinknecht: 'Innovative output and a firm's propensity to patent. An empirical investigation', in *Research Policy*, Vol. 28 (1999), p. 615-624.

Table 1: Factors that influence the probability that a firm will participate in FP 4 and/or FP 5. Evidence from the Dutch, German and French CIS. Summary of logit estimates						
	Netherlands		**Germany**		**France**	
	Coeffi-cients:	z-values:	Coeffi-cients:	z-values:	Coeffi-cients:	z-values:
Collaboration with suppliers	-0,05	-0,39	0,14	0,98	0,14	2,60**
Collaboration with clients	0,27	2,04**	0,54	3,98**	0,37	6,27**
Collaboration with competitors	0,01	0,07	0,47	3,48**	0,13	1,91*
Collaboration with universities	0,74	5,64**	0,82	6,32**	0,64	11,08**
Firm size (employees)	0,00003	2,33**	$4{,}53e^{-06}$	1,88*	0,0001	6,44**
Firm's R&D intensity minus sector average	0,017	4,58**	0,01	3,09**	1,48	8,26**
Firm holds valid patents	0,59	6,28**	0,48	4,12**	0,25	5,26**
Firm's most significant market is international	0,26	2,75**	0,26	2,30**	0,30	6,32**
Constant term	-2,44	-35,32**	-2,65	-30,15**	-2,38	-59,03**
Number of observations	4.526		3.853		12.935	
Pseudo R-squared	0,20		0,36		0,20	
* significant at 90% level ** significant at 95% level						

V Do PF participants have higher sales of innovative products?

We analyze the impact of participation in FPs on sales of innovative products ('new to the market') rather than on imitative products ('new to the firm'). As indicated above, it is not sufficient to check whether FP participants have higher than average sales of innovative products. It might well be that firms are not 'good' because they participate in an FP, but they are participating in an FP because they are 'good'. We therefore correct our estimates by means of a Heckman selection equation.

We also control for a number of other factors that contribute to sales of innovative products. Inclusion of these other factors implies that we test a number of hypotheses. Among these are the following:

- Firms that collaborate on R&D should (ceteris paribus) produce higher innovative output, as they enjoy a number of advantages. First, they can share costs and risks which should enhance subsequent sales. Second, they can exploit complementary knowledge, which should save costs and shorten the time-to-market. Being earlier on the market should favour sales. Third, firms that collaborate can 'internalize' positive externalities; their collaboration partners turn from competitors (or imitators) into supporters of the new product, which should be favourable for sales. Finally, collaborators should have a higher chance of determining a dominant standard. All this would lead us to expect that firms that engage in R&D collaboration should have (ceteris paribus) higher sales of innovative products than those who do it alone.

- By the reasons just mentioned, we would expect FP participants also to show higher sales, although much of the R&D in a Framework Program is pre-competitive. Considering the time distance between, on the one hand, FP 4 (1994-98) and FP 5 (1998-2002) and, on the other hand, the new product introduction period (2002-2004), we would expect that advantages derived from FP participation should be discernible in sales of innovative products in the year 2004. Perhaps this holds less for FP 5, but it should certainly hold for FP 4.
- Many people who use the output indicator from the CIS ignore an important limitation of this indicator: It is not suitable for comparisons across industries. The typical lengths of the life cycles of new products can differ between industries. For example, in food or clothing industries, life cycles tend to be short, while in aircraft construction they are fairly long. An industry with shorter (longer) life cycles will exhibit higher (lower) rates of new product introduction.[4] As questions about length of life cycles tend to be badly reported in postal surveys, we use as an alternative the average sales of innovative products in a firm's sector of principal activity. Inclusion of this latter variable implies that we actually explain whether a firm's sales of innovative products deviate from the average of the firm's sector of principal activity. This variable should also capture unobserved sector-specific influences on innovation. In a number of tentative estimates, it turned out that sector dummies (including versions inspired by the Pavitt taxonomy) became insignificant, once we included this variable. Of course, we expect this variable to be highly significant, implying that an individual firm's sales of innovative products are strongly determined by the average standards of its sector.
- As we are interested in a possible <u>increase</u> of innovative sales in 2004 (compared to 2000), we also include a firm's sales of innovative products in 2000 as an explanatory variable. We assume that participation in FPs during 1994-98 and 1998-2002 will have effects on innovative sales in 2004, but not yet in 2000.

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[4] Explaining a firm's innovative sales, Brouwer & Kleinknecht found that life cycle length is indeed highly significantly negative. This confirms that the longer are the life cycles in a sector, the lower is the probability that a firm will have introduced new products and the higher are the shares of new product sales in total sales. See Brouwer, E. & A. Kleinknecht: 'Firm size, small business presence and sales of innovative products', in *Small Business Economics*, Vol. 8 (1996), p. 189-201.

- As R&D intensity can differ tremendously across sectors, we use the deviation of a firm's R&D intensity from the average of its sector of principal activity. Of course, we expect firms with above-average R&D intensities to also show sales of innovative products above sector average.
- We control for firm size. By the reasons mentioned above, we have no a priori expectations about the sign of the coefficient of firm size. Typical advantages of smaller firms (notably flexibility) might be offset by typical disadvantages (e.g. lack of resources).
- Following evidence for 'demand-pulled' innovations,[5] we include growth in a firm's total sales during 2002-4 as a control variable.
- Finally, we include control variables for two more types of firms. First, for firms that are part of a foreign conglomerate. Such firms may introduce new products from the mother company, without necessarily performing R&D themselves. Second, we control for firms that underwent a major organizational change due to a merger or acquisition. The problem with these types of firms is that, due to organizational turbulence, the quality of data reporting in a survey may be poor.

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[5] The 'demand-pull' hypothesis goes back to the seminal work by J. Schmookler: *Invention and economic growth*, Cambridge: HUP, 1969. For a recent survey of research on demand-pull see Brouwer, E. & A. Kleinknecht (1999): 385-391.

Factors that influence logs of sales of innovative products per employee in 2004 ('first on the market'; introduced during 2002-2004)						
Independent variables: (measured in CIS 3, covering the year 2000)	**Netherlands**		**Germany**		**France**	
	Coeffi-cients:	t-values:	Coeffi-cients:	t-values:	Coeffi-cients:	t-values:
Firm collaborated on R&D with suppliers (d)[$]	-0,13	0,63	-0,07	-0,28	-0,05	-0,50
Firm collaborated on R&D with clients (d)	-0,19	-0,91	-0,25	-0,91	-0,11	-0,94
Firm collaborated on R&D with competitors (d)	-0,07	-0,36	0,09	0,29	-0,07	-0,55
Firm collaborated on R&D with universities (d)	-0,11	-0,52	-0,07	-0,30	0,07	0,58
Industry average of logs of sales of innovative products per employee	0,90	4,54**	0,13	0,47	0,39	2,56**
Firm's R&D intensity minus industry average	0,03	2,11**	0,007	0,82	0,78	1,43
Log of firm's sales of innovative products per employee in 2000	0,48	7,18**	0,54	5,69**	0,32	8,66**
Firm size (number of employees)	-0,00001	-0,36	$-7{,}77e^{-06}$	-1,95*	$-1{,}31e^{-06}$	0,79
Demand-pull (growth of firm's sales in 2002-4)	0,003	3,72**	0,003	0,71	-0,00003	0,74
Firm is part of a foreign conglomerate (d)	0,06	0,48	-0,004	-0.01	-0,04	0,69
Firm had a merger or acquisition leading to >10% turnover change in 1998-2000 (d)	0,34	1,48	0,04	0,10	0,34	1,81*
Firm held patents valid in year 2000 (d)	0,74	4,13**	0,23	0,68	0,03	0,22
Interaction term: Firm participated in FP and has an above-average R&D intensity	**0,05**	**0,13**	**-0,79**	**-1,84***	**0,03**	**0,32**
Interaction term: Firm participated in FP and has a below-average R&D intensity	**1,02**	**1,73***	**-0,81**	**-1,90***	n.a.[#]	n.a.[#]
Constant term	-4,91	-5,19**	0,56	0,61	1,03	2,21**
Number of observations	1176		494		1217	
Significance of Chi^2 test	0,0000**		0,000**		0.000**	
* significant at 90% level ** significant at 95% level [$] (d) = dummy variables [#] Variable was dropped due to collinearity.						

Heckman selection equation:						
Independent variables: (d) = dummy variables	**Netherlands**		**Germany**		**France**	
	Coeffi cients:	t-values:	Coeffi-cients:	t-values:	Coeffi-cients:	t-values:
Firm's R&D intensity minus industry average	0,003	0,50	0,003	0,49	-0,20	-0,47
Log of firm's sales of innovative products per employee in 2000	0,17	5,84**	0,14	2,77**	0.04	1,55
Firm size (number of employees)	0,0001	2,99**	$2{,}33e^{-06}$	0,71	0,0002	4,77**
Interaction term: Firm participated in FP and has an above-average R&D intensity	0,22	1,01	-0,09	-0,29	-0,14	1,79*
Interaction term: Firm participated in FP and has a below-average R&D intensity	0,14	0,41	0,03	0,11	n.a.[#]	n.a.[#]
Firm held patents valid in year 2000 (d)	0,44	5,18**	0,73	5,78**	0,61	7,87**
Constant term	-1,22	-9,53	-0,82	-2,62**	-0,37	-3,45**
Number of observations	1176		494		1217	
* significant at 90% level ** significant at 95% level [$] (d) = dummy variables [#] Variable was dropped due to collinearity.						

A number of observations differ between the three countries. First, the deviation of a firm's R&D intensity from the average of its sector of principal activity is a significant predictor of innovative sales in the Netherlands. It is only weakly significant, however, in France and insignificant in Germany. Second, industry-average sales of innovative products are highly significant in the Netherlands and in France, but not in Germany. Third, the 'demand-pull' variable is highly significant in the Netherlands but is insignificant in Germany and France. Forth, firms holding valid patents in year 2000 have significantly higher sales of innovative products in the Netherlands, but not in Germany and France. We have the impression that the insignificance of various variables in Germany might come from some noise in the German data, German response rates and sample sizes being smaller than in the Netherlands and in France. Firm size does not make a difference in the Netherlands; in Germany, smaller firms seem to have higher sales of innovative products (significant at 10% level).

The following observations are consistent between the three countries:

- R&D collaboration with whatever partner (suppliers, clients, competitors or universities) has no impact on innovative sales in both countries;
- Not surprisingly, in all three countries, a firm's innovative sales in 2000 are a strong predictor of innovative sales in 2004;
- Being part of a foreign conglomerate or having had a merger or acquisition appears to have little impact on innovative sales;
- Participation in FP 4 (1994-98) and/or FP 5 (1998-2002) has in all three countries hardly any impact on innovative sales. This generally holds for other versions of our estimates, e.g. when taking simply a dummy variable for 'participation' or when using various types of interaction terms (e.g. firms size times 'participation' or sector times participation).

Besides the versions documented in the table, we experimented with numerous alternative regression specifications in order to test the robustness of the results. These robustness checks were satisfactory. Most of the coefficients in the table changed only very little when adding (or omitting) some control variables or when defining them slightly differently.

While many outcomes are intuitively plausible, two findings merit closer discussion. First, firms that collaborate on R&D with clients, suppliers, competitors or public institutions do not perform better or worse than firms that do it alone. Second, participants in FP 4 and/or 5 do not have more innovative sales than non-participants. In both cases, there are good reasons to expect that innovative inputs should be used more efficiently as firms that collaborate on R&D or participate in Framework Programs have a number of distinct advantages:

- They can share costs and risks;

- They can use complementary knowledge;
- They can internalize each other's knowledge spillovers; i.e. the project partners are being turned from competitors (or imitators) into defenders of the innovation;
- They have a higher chance of determining the dominant standard in the market.

How does it come that we nonetheless find no significant effect of R&D collaboration or of FP participation on sales of innovative products? Of course, participation in collaborative R&D or in FPs also has obvious disadvantages. First, the management and coordination of the collaborative projects absorb some time and effort. Second, notably in inter-country collaboration, cultural mismatch and physical (travel) distance between partners can play a negative role for efficiency. Third, collaboration partners often need to undertake extra efforts for the protection of their intellectual property, for example by acquiring patents or copyrights, as they want to be protected against opportunistic behaviour of their partners. Such factors lead to a loss of time and money and this will compensate some of the obvious advantages from collaboration.

Another possible explanation could relate to the type of projects that is undertaken in collaboration. In principle, the Framework Projects are 'pre-competitive'. This would lead us to expect that commercial exploitation of results should follow the projects with considerable time lags. As we measured participation in FP 4 (1994-98) and FP 5 (1998-2002), we would expect that at least participation in FP 4 should have some results during the period covered in CIS 4 (i.e. innovations introduced during 2002-4).

Another question relates to why firms collaborate. Suppose, you have an idea for an innovative project that looks like a gold mine. Why should you invite collaboration partners with whom you have to share the gold mine? Two possible answers to this question could be: (1) The firm has not enough readily available knowledge for doing it alone; or (2) the project looks promising, but is surrounded with strong risks and uncertainties and therefore you feel a need for sharing costs and risks. The latter could apply to somewhat exotic technologies such as nano technology or super conductivity where it is important to keep up with developments, although commercial use may be far away. In such cases, cost sharing through collaborative research may be more than welcome.

It is reasonable to expect that firms will do the least risky and most profitable projects themselves, independently of whether they receive some funding from the EU or not. Successful application for participation in an EU funded project may lead them to doing perhaps also the more risky projects.

From the considerations above, one would expect that EU-FP projects are, in one or the other way, more risky, more complex, more distant from the firm's core competencies, or, putting it briefly: in one or the other way more 'difficult'. Evidence from an independent survey among FP participants as well as case studies among participants do indeed confirm this (Polt et al., 2007). Against this background, the above insignificant coefficients for R&D collaboration and for participation in FPs would in fact carry a positive message: in spite of doing more 'difficult' projects, futures sales from the difficult projects are not less than the sales from 'easier' projects.

Independently of this, one can also investigate whether participation in FPs leads to extra R&D efforts. If it holds that subsidization of R&D through the Framework Programs leads to extra R&D efforts, then the above insignificant coefficients imply that the extra R&D (due to subsidization by the EU) is not less efficient than the R&D that firms would be ready to undertake from their own money (without subsidization).

VI Do subsidies lead to increased R&D efforts?

Ideally, one would like to answer the following question: *How many Euro of R&D will a firm spend, on average, for each Euro of R&D subsidies received?* Answering this question would require firm-level data on R&D budgets prior to and after subsidization <u>and</u> on amounts of subsidies received. The latter data are not available in the Community Innovation Survey. Fortunately, there is still a second-best solution. The CIS data allow answering the following question: *Does participation in FP 4 (1994-98) and/or FP5 (1998-2002) have an effect on the <u>change</u> in a firm's R&D intensity between 2000 and 2004?*

We estimate an equation that explains a firm's R&D intensity in 2004, including, besides some control variables, a dummy variable on whether the firm participated in FP 4 and/or FP 5 and the firm’s R&D intensity in 2000. It would have been better if we had information only on participation in FP 5 (1998-2000), but participation in FP 4 and/or FP 5 is not asked for separately in the CIS questionnaire.

In interpreting our results, one should be aware that the impact of participation in an FP on a firm's R&D budget is likely to differ considerably between smaller and larger firms. The smaller a firm, the bigger should be the impact of participation, simply because the relative importance of the R&D subsidy to the firm's total R&D budget is likely to be higher among smaller firms. In larger firms that are likely to have multiple R&D projects, the EU subsidy may only be a minor share of the total R&D budget. This is likely to result in smaller (and possibly insignificant) coefficients among larger firms. We therefore include a cross-term in our equation: participation in FPs times firm size class. In order to correct for self selection we again include a Heckman term.

Does participation in FP 4 (1994-98) and/or FP5 (1998-2002) have an effect on changes in R&D intensities between 2000 and 2004?
(Estimates with interaction terms: participation times firm size class)

	Netherlands		**Germany**		**France**	
Independent variables:	Coeffi-cients:	z-values:	Coeffi-cients:	z-values:	Coeffi-cients:	z-values:
R&D intensity in 2000	0,47	12,38**	0,23	2,11**	0,44	4,43*
Firm size (employees)	-0,00009	-1,44	-0,00001	-2,12**	-3,15e^{-17}	-0,04
Interaction term: smaller firm times participation in FP4 or FP5	0,69	1.82*	0,72	2,31**	1,78	2,49**
Interaction term: medium-sized firm times participation in FP4 or FP5	0,18	0,78	-0,55	-1,21	0,49	1,13
Interaction term: big firm times participation in FP4 or FP5	0,07	0,20	-0,02	-0,05	-0,39	-0,91
Firm's most significant market is international	0,33	3,05**	-0,20	-0,93	0,62	1,56
Firm holds valid patents by the end of 2000	0,26	2,37**	0,14	0,58	0,37	0,95
Constant term	1,50	5,32**	0,49	0,72	-2,39	-3,28**
Selection equation:						
R&D intensity in 2000	0,07	3,88**	0,11	3,71**	0,11	3,51**
Firm size (employees)	4,83e^{-06}	0,34	5,49e^{-07}	0,17	0.00004	3,06**
Firm participated in FP4 or FP5	0,46	4,10**	0,27	2,52**	1,64	13,49**
Constant term	-0,86	-26,77**	-0,58	-3,32**	-1,35	-9,35
Number of observations	2519		1113		1795	
Significance of Chi^2 test	0,0034**		0,0000**		0.1019#	

* significant at 90% level

** significant at 95% level

The Chi-square test indicates that a Heckman specification is not really necessary, since we cannot reject (at the 5 or 10% level) the null-hypothesis of independence between the selection and regression equations. In other words, in the French case, a simple OLS estimate would have been sufficient.

The above estimates show that, not surprisingly, firms having high R&D intensities in 2000 again have high R&D intensities in 2004. Moreover, in the Netherlands, firms that are more internationally oriented and firms that hold patents have significantly higher R&D intensities in 2004 compared to locally oriented firms or firms having no patents. This observation does not hold for Germany and France. As expected, distinction by firm size makes an important difference in all three countries. Participation by smaller firms (less than 100 employees) leads to a strong and significant increase in R&D intensities. Participation in FPs by medium-sized (100-499 employees) and by large (500 and more employees) firms, however, has no significant impact on R&D intensities.

The coefficients for firms with less than a hundred employees are 0.69 in the Netherlands and 0.71 in Germany. Tentative calculations suggest that these coefficients come down to quite a substantial change in R&D intensities. After control for other influential factors, a firm with less than a hundred employees will, on average, increase its R&D budget between the year 2000 and year 2004 by roughly a 100% if it participates in FP 4 and/or FP 5. In the case of France, the coefficient of 1.78 indicates that R&D intensity would even more than double. In interpreting these estimates we need to take into account that the confidence intervals around these estimates are rather wide. Therefore, the point estimates need to be read with caution. We nonetheless trust that there is a significant increase in R&D efforts if smaller firms participate in a Framework Program.

VII Summary, conclusions and discussion

We investigated the possible chain of causality from subsidies for R&D collaboration in EU Framework Programmes to innovative output. The most important intermediary variable is (collaborative) R&D both inside and outside the EU Framework Programs. Results from our logit analysis on Framework Programme participation suggest for The Netherlands, Germany and France that Framework Programmes attract the elite of innovators in Europe. This is an important finding since it confirms the well-known self selection biases that are associated with many subsidy programs. Therefore in exploring the impact of FP participation on innovation we employed a Heckman type of analysis in order to correct for these biases.

Innovative output does not seem to be enhanced by participation in EU Framework Programs in France, Germany, and in The Netherlands. This result remains valid after numerous robustness checks. Another remarkable result is that innovative output is neither enhanced by other forms of R&D collaboration outside the Framework Programs. We try to offer explanations for these counter-intuitive findings. One might wonder whether our failure to find an effect has to do with the time-lags between exogenous and endogenous variables that are dictated by the structure of the data. Of course, the available data are not ideally suited to our purpose. On the other hand, a time lag between participation in FP 4 (1994-98) and/or FP 5 (1998-2002) and innovative output produced during 2002-4 seems to be not too far from what we want to measure.

In interpreting our outcomes, one should be aware of evidence that collaborative projects undertaken under the EU Framework Programs tend to involve higher scientific and technical risks, they are scientifically and technically more complex, involve longer time horizons and are (due to regulatory requirements) farer from market introduction (i.e. they need to be 'pre-competitive'), compared to 'normal' (collaborative or other) R&D projects (Polt et al., 2007). In short, collaborative R&D under the Framework Programs tends to tackle projects that are, in one way or the other, more 'difficult' than normal R&D projects. Against this background, our finding of insignificant coefficients does not necessarily prove that EU Framework Programs are inefficient. In any case, sales of innovative products from more difficult FP projects are not less than the sales from more easy R&D projects outside the FPs.

Our test on 'input additionality' with respect to extra R&D carries a positive message for firms with less than a hundred employees (among larger firms we find no such effects). That is, we tested whether FP program participation resulted in crowding out of private investment in R&D. For that purpose we have analysed growth of R&D expenditures in the period following participation in Framework Programs. We find substantially larger R&D intensities among smaller firms in the period after participation in an FP, which is between 0 and 8 years after the FP participation. This result was found for the Netherlands, Germany and France with the latter showing the largest effect. The data did not allow for precise measuring of crowding out, but this finding suggests that crowding out effects of FP programmes are fairly limited in the countries under scrutiny in this paper.

To conclude, EU Framework Programmes do not have a positive impact on innovative output. Given the more 'difficult' character of these projects, our insignificant outcomes do not necessarily carry a negative message. On the other hand, we do find quite considerable 'input additionality', at least among smaller firms. It seems that the FP programs do serve a purpose in the sense that they could correct under-investment by private firms in R&D.

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