University-industry collaboration and firms' innovative performance: evidence from French Data

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Abstract:

In this paper we present an econometric analysis of the effect of cooperation with universities and establishments of higher education on firms' innovative performance. First, using the Heckman's 2SLS, we find no sample selection associated to the probability to innovate. Second, based on an exogeneity test for a simultaneous equation Tobit, we reject the possible endogeneity. Finally, in order to have more robust results, we undertake a median regression which better handles large outliers. Our results suggest that cooperation with academia has a positive influence on firms' intensity of innovation.

Key words: Collaboration; France; Innovation; Universities

JEL classification: O31 - O33 – C34

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1. Introduction

University-industry collaborations have attracted considerable attention in the last few decades. Several papers have pointed to the importance of scientific research for technological change, innovation and economic performance. Universities are no longer simply considered as “ivory towers” that perform research for the own sake of knowledge but as real actors in the knowledge-based economy (Mowery and Sampat, 2005). In addition to education and research, universities are now playing a third role: they are responsible for the diffusion of knowledge and techniques that may contribute to industrial innovation (Mansfield, 1996). As stated by the literature on national innovation systems, the university’s role is to transfer knowledge to firms through training of students (future skilled employees) and the collaboration with firms. Also, it is well known that innovation is an interactive process (Lundvall, 1992). Indeed, because an important part of the knowledge needed by firms is difficult to codify, close collaboration with other actors including universities is essential to the innovative process. As reported by Grossman and Helpman (1992), resources and knowledge can be pooled to generate new knowledge which spills over to researchers who will use this knowledge to produce further knowledge, creating a cumulative process.

Several concepts are used in the literature to describe the more active role that university plays in the transfer of academic research. Etzkovitz (1983) defined universities that play a more active role in the transfer of academic research as “entrepreneurial universities”. Etzkovitz and Laytesdorff (1997) introduce the concept of Triple Helix to describe the increasing position of universities in innovation. According to this thesis, innovation is the result of the interaction of three helixes: university, industry and government.

Moreover, Rosenberg and Nelson (1994) contend that basic research done in university stimulates the R&D performed in industry. University research has thus an indirect effect on innovation since it encourages industrial R&D. Based on a state-level analysis; Jaffe (1989) concludes that improving a university’s research system increases local innovation. More frequent interactions with universities can increase the firm’s ability to recognize, absorb and apply externally received knowledge which is critical to their innovative capabilities. Therefore, prior related knowledge enables firms to increase their absorptive capacity (Cohen and Levinthal, 1990)

Many empirical studies find support for the idea that interactions with universities positively influence innovation in firms. For example, Mansfield (1998) reports that 15% of the new products developed in the United States between 1986 and 1994 could not have been developed without academic research. These studies are divided into two types.

Studies that examines the impact of partnerships on the probability to innovate (Kaufmann et Tödling, 2001; Rouvinen, 2002; Monjon et Waelbroeck, 2003; Freel et Harrison, 2006 ; Vega-Jurado et al., 2008 ; Eom et Lee, 2010). Based on French data, Monjon and Waelbroeck (2003) find that collaboration with foreign universities increases the probability to introduce a radical innovation (a product technology new to the market). Rouvinen (2002) shows that cooperation with universities has a positive impact on product innovation but no impact on process innovation.

The second type of studies investigates the effect of collaboration on the firm's innovation output (Belberdos et al. 2004; Mohnen et al.,2005; Lööf and Broström, 2008 ; Aschhloff and Smith, 2008 ; Frenz and Ietto-Gillies, 2009 ; Eom and Lee, 2010). Thereby, Belberdos et al. (2004) find evidence that R&D cooperation with universities and research institutes in Deutschland increases firm's productivity. Lööf and Bostöm (2006) find that collaboration with universities for large Swedish manufacturing firms has a positive impact on innovative sales and the propensity to apply for patent. Using the Korea Innovative Survey, Eom et Lee (2010) find a positive impact of cooperation with universities on patents from new product innovation but no effect on sales and labor productivity.

This work is part of this second type of studies. As far as we now, there is no evidence in France on how linkages with universities affect firms' innovation intensity. Moreover, this work achieves some methodological improvement. It is likely that the most efficient firms may be more inclined to collaborate with universities for their innovative activities. This may raise an endogeneity problem that most studies do not control for.

The objective of this paper is to analyze the impact of knowledge emanating from universities and establishments of higher education on firms' innovative performance. We also test for the possible endogeneity of cooperation with universities.

The remainder of this article is organized as follows. Section 2 describes data and variables. Section 3 presents summary statistics. The econometric methodology is presented in Section 4. In Section 5, we discuss our results and investigate their robustness before we draw conclusions in Section 6.

2. Data

The data used are taken from the fifth French Community Innovation Survey (CIS). It was undertaken in 2007 and collects information on the innovative behavior of manufacturing firms with more than 19 employees. Firms are asked whether they have introduced at least one product innovation during the period 2004-2006. We consider a firm to be innovative if it answered yes to this question.

The CIS asks innovative firms to estimate the share of sales related to the introduction of new products. This estimate can be considered as a measure of innovative performance. Furthermore, CIS distinguishes between products that are only new to the firm and those that are new to the market. The former can be considered as simple imitations of products that are already available in the market whereas the latter are true innovations. We thus prefer to restrict our analysis to products that are new to the market.

Most importantly, the survey provides information on firms' interactions in their innovative activities, including interactions with universities and establishments of higher education. Firms are first asked whether they have cooperated with partners for innovation. If yes, they then have to specify with whom they have collaborated and in which area (France, Europe and other parts of the world).

CIS also provides information about research and development (R&D) intensity measured as the amount spent on R&D in € thousands per employee. We distinguish between two types of R&D: internal R&D defined as investment in in-house R&D and external R&D which is bought-in from outside the firm.

We finally include five control variables. We control for firm size measured as the log of number of employees and belonging to a group which is measured as a dummy. Because competition may affect innovative performance, since firms that export to international markets are more exposed to competition, we consider two other variables: the presence in European markets the presence in international markets. We also include 11 industry dummies (the machinery industry is omitted) that are presented in Appendix A.

3. Summary statistics

Table 1 below gives summary statistics. Entries in column 2 and 3 are related to all innovative firms while the next two columns correspond to firms that have cooperated with universities or establishments of higher education. In the survey, 2172 firms introduced at least one product innovation during the period 2004-2006. The presence in international market is clearly observed: 85% of the firms sold their product in European markets and 72% were present in other international markets. Out of the 2127 firms, 1633 are part of a group and the average size of firms in the sample is 525 employees. See Appendix B for the correlation matrix.

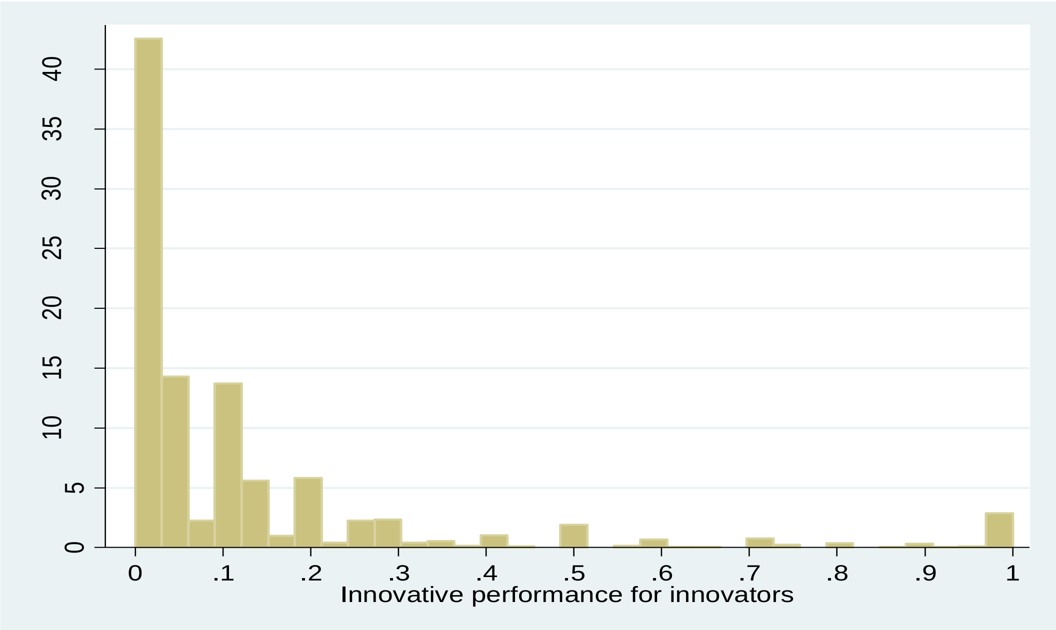
Among innovative firms, 511 firms have collaborated with universities or establishments of higher education. These firms are on average larger then all innovative firm. We also observe that the average innovative performance of firms cooperating with academia is greater than the average performance of all innovative firms. Moreover, internal and external R&D intensity are higher for firms that cooperate with universities.

TABLE 1: summary statistics

Variables	Innovative firms		Cooperating firms	
	Mean	s.d.	Mean	s.d.
Innovative performance	0,126	0,212	0,148	0,223
Internal R&D intensity	0,026	0,061	0,042	0,078
External R&D intensity	0,003	0,023	0,005	0,014
Cooperating with university	0,235	0,424	–	–
Size	5,309	1,279	6,000	1,331
Group	0,752	0,432	0,871	0,336
European markets	0,854	0,353	0,937	0,243
International markets	0,715	0,452	0,845	0,362
Vehicles	0,096	0,295	0,088	0,284
Chemicals	0,118	0,323	0,200	0,400
Machinery	0,099	0,298	0,112	0,315
Electrical	0,173	0,378	0,205	0,404
Food	0,135	0,342	0,104	0,305
Textile	0,065	0,247	0,039	0,194
Wood	0,072	0,258	0,043	0,203
Plastic Rubber	0,065	0,246	0,055	0,228
Non-metallic	0,048	0,214	0,041	0,199
Basic metal	0,092	0,289	0,098	0,297
N.E.C	0,037	0,190	0,016	0,124
Number of observations	2172		511	

The average share of turnover relative to products new to the market for all innovative firms is 12, 6 %. Figure 1 shows the distribution of innovative performance. Out of the 2172 firms, 1511 reported a positive turnover from product innovation and 61 reported that their turnover is entirely due to innovative product**.** Thus, nearly 31% of innovative firms reported a zero turnover from products new to the market.

FIGURE 1: Innovative performance distribution for innovators



4. Methodology

As this has been demonstrated, our data contains a large proportion of zeros yielding a censored dependent variable. To deal with these too many zeros, we use the Tobit model formulated by Tobin (1958). The regression model with censoring from below at zero is:

$$y^* = x'\beta + \varepsilon$$

where y^* is an unobserved latent variable and the error term ε $\sim N\left[0,\sigma^2\right]$ has a constant variance σ^2 across observations (Cameron and Trivedi, 2005).

The variable y is related to the latent variable y^* through the following rule:

$$y = \begin{cases} y^* & if \;\; y^* > 0 \\ \_ & if \;\; y^* \leq 0 \end{cases}$$

In this work, the zero innovative performance can be interpreted as a left-censored variable which equals zero when $y^* \leq 0$. The sample consists then on censored and uncensored data.

Moreover, because only firms that have introduced a new product between 2004 and 2006 have to complete the question about innovative performance, CIS data can be subject to a selection problem**.** It is also likely that the decision to innovate and innovative performance may be explained by different independent variables. In order to take account of these two features, we estimate a Heckman selectivity model consisting of two equations (Green, 2003). The first is a probit equation which indicates if a firm innovates or not, and the second one explains the extent of innovative performance.

The two-equation model comprises a selection equation for y_{1i} that is specified in terms of a latent variable y_{1i}^* indicating that the firm *i* innovates if the incentives to do it are sufficiently large ($y_{1i}^* > 0$)

$$y_{1i} = \begin{cases} 1 & if \;\; y_{1i}^* > 0 \\ 0 & if \;\; y_{1i}^* \leq 0 \end{cases}$$

and an outcome equation for y_{2i} determined by a second latent variable y_{2i}^*, where:

$$y_{2i} = \begin{cases} y_{2i}^* & if \;\; y_{1i}^* > 0 \\ - & if \;\; y_{1i}^* \leq 0 \end{cases}$$

Here y_{2i} is observed only when $y_{1i}^* > 0$ and is missing when $y_{1i}^* \leq 0$.

We can therefore write:

$$y_{1i}^* = x_{1i}b_1 + \varepsilon_{1i}$$

$$y_{2i}^* = x_{2i}b_2 + \varepsilon_{2i}$$

where x_{1i} and x_{2i} are vectors of explanatory variables, b_1 and b_2 vectors of parameters to be estimated and ε_{1i} and ε_{2i} are normally distributed error terms that might be correlated.

In order to test for sample selection bias, we rely on Melino's test (Melino, 1982) which is based on a t-test on the inverse mill's ratio.

Furthermore, the hypothesis we are trying to test is that cooperation with universities enhances firms' innovative performance. However, cooperation may itself be determined by innovative performance since firms that are heavily engaged in innovative activities may be more likely to attract partners for a knowledge transfer in the opposite direction. This raises a problem of endogeneity that we tackle by estimating a simultaneous equation Tobit using the approach of Smith and Blundell (1986) which consists of two steps.

Firstly, using ordinary least squares (OLS) we estimate the relationship between cooperation with universities and a set of instrumental variables Z_{2i}.

$$y_{2i} = \beta_1 X_{2i} + \beta_2 Z_{2i} + v_{2i}$$

The instrumental variable that is used in this study is investment tax credit related to innovative projects. It directly influences the cooperation with universities and has no impact on innovative performance. In France, investment tax credit related to innovative projects is a tax measure that aims to support firms' R&D efforts. This tax shield is particularly in favor of cooperation with public research laboratories. Indeed, when R&D expenditures involve contracts done with universities, public laboratories, business and engineering schools, the tax shield rates are doubled and can cover a significant part of the project.

In the second step, we estimate the relationship between innovative performance and cooperation with universities using a Tobit model by maximum likelihood. We include in the independent variables the estimated residuals from the first stage:

$$y_{1i} = \beta X_{1i} + \hat{v}_{2i} + \varepsilon_{1i}$$

It is thus possible to implement a simple test of weak exogeneity by considering the following hypothesis of weak endogeneity $H_0 : \alpha = 0$. We reject this hypothesis if -using a Student test, the coefficient α is statistically significant.

5. Results

Table 2 below presents the regression results. Column (1) analyzes the determinants of innovation using the Probit model. The dependent variable measures whether a firm introduced a new product into the market. The value of this variable is one if it does and 0 otherwise. Belonging to a group and firm size appears to increase the probability to innovate. The presence in international markets is also significantly associated with the decision to innovation and there are some sectoral differences.

Column (2) shows the results for the Tobit model examining the impact of cooperation with universities and establishments of higher education on firms' innovative performance. The main finding is that university collaboration positively influences innovation intensity. This result is consistent with the finding by Lööf and Boström (2006) and Aschhloff and Smith (2008) in Sweden and Germany respectively, that R&D cooperation with universities and research institutes has a positive influence on the share of sales due to market novelties. Moreover, the internal R&D expenditures are positively linked to innovative performance whereas external R&D expenditures are insignificant and negative. Turning to control variables we do not find that firm size and international presence affects innovative sales per employee. The coefficient of group shows a negative and statistically significant sign suggesting that there is a negative association between affiliation to a group and innovative performance. Finally, there are some industry effects.

To test for the possible sample selection related to the probability to innovate, we use an econometric model with a selection equation. Column (3) considers the Heckman's two stage least squares. The inverse Miller's ratio (Inv. MILLS) is insignificant rejecting the existence of sample selection bias.

Next, in order to test for the possible endogeneity of university cooperation, we estimate a simultaneous equation Tobit. If residuals estimated from the regression of university cooperation and introduced in the Tobit model are significantly different from zero, we are facing a problem of endogeneity. Appendix C presents the regression of university cooperation where investment tax credit related to innovative activities is used as an instrument. The regression result of the first stage shows that it is statistically significant indicating the relevance of this instrument.

TABLE 2 : Regression results

	(1)		(2)		(3)		(4)		(5)	
	coeff.	t	coeff.	t	coeff.	t	coeff.	t	coeff.	t
Group	0,118*	1,75	-0,043*	-1,76	-0,007	-0,53	-0,041*	-1,66	-0,008	-1,37
Size	0,261***	9,1	0,007	0.83	0,004	0,68	-0,007	-0,49	0,006***	2,99
European market	0,387***	4,69	-0,004	-0.09	-0,008	-0,44	-0,011	-0,26	0,000	-0,04
International market	0,346***	4,75	0,026	0.87	0,032	2,11	0,022	0,74	0,015**	2,49
Internal R&D	_	_	0,385***	2.76	0,184	2,4	0,365***	2,6	0,163***	4,32
External R&D	_	_	-0,320	-1.15	-0,062	-0,32	-0,331	-1,22	-0,074	-0,82
Coop_university	_	_	0,068***	3.22	0,024	2,15	0,254*	1,7	0,022***	3,9
Vehicles	-0,189	-1,54	0,041	1.44			0,047	1,63	0,010***	3,23
Chemicals	-0,034	-0,25	-0,024	-0.89			-0,034	-1,24	0,010	-0,11
Electrical	0,138***	1,17	0,007	0.21			0,000	0	0,009	0,01
Food	-0,395***	-3,13	-0,053**	-1.91			-0,043	-1,46	0,009**	-2,34
Textile	-0,336***	-2,63	0,116***	2.66			0,125***	2,84	0,011	0,38
Wood	-0,659***	-4,8	-0,025	-0.58			-0,012	-0,27	0,011**	-2,29
Plastic Rubber	-0,096	-0,65	0,139**	2.42			0,141**	2,46	0,011	0,65
Non metallic	-0,202	-1,2	-0,013	-0.36			-0,002	-0,05	0,012	-1,5
Basic metals	-0,544***	-4	0,062	1.31			0,077	1,59	0,010	-1,06
N.E.C	-0,277	-1,48	0,043	1.23			0,059	1,57	0,013	0,1
Constant	-1,714***	-11,05	-0,001	-0.02	0,061	0,87	0,038	0,69	0,013	0,63
Residuals							-0,192	-1,21		
Inv. MILLS					0,028	0,85				
numb. Obs.	4900		2172		4900		2172		2172	
R^2	0,14		0,07				0,07		0,02	
sigma			0,286				0,286			
left_censored			661		2728		661			
uncensored			1511		2172		1511			
right-censored			0				0			
rho					0,131					
Chi-squared(d.f)					17,94(7)					

The second stage estimation is presented in Column (4) and reveals that residuals are not statistically significant. Consequently, we confirm the hypothesis of exogeneity and conclude that cooperation with universities influences innovative performance and not the other way around. Thus a simple Tobit regression is sufficient to determine the effect of university cooperation on innovative performance.

Finally, to further evaluate the robustness of these results, we estimate a quan tile regression at the median. The advantage of the median regression also called "least absolute-deviation regression" is a better handling of problems of large outliers. In addition, whereas Tobit model makes strong assumptions about the conditional data distribution, the quantile regression make no assumption about the parametric distribution of regression errors. Results of the quantile regression are shown in Column (5) where the dependent variable is innovative sales per employee. Cooperation with universities and internal R&D still significant. Firm size and presence in international markets become significant while belonging to a group has no effect on innovative performance. This implies that larger firms are more innovative then smaller ones and that firms that export are more efficient than those that do not sell in international markets.

6. Conclusion

Our analysis focuses on the effect of cooperation with universities on firms' innovative performance. Using an overall sample of 2171 observations from the fifth French Community Innovation Survey, we find that cooperation with academia positively influences firms' intensity of innovation. Moreover, we show that internal R&D expenditures positively influence innovative sales per employee. The study reveals some differences between large firms and small ones and across manufacturing sectors. Finally, the results show that the level of competition, captured through the presence of firms on international markets, has a positive impact on intensity of innovation.

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Appendix A : Industrial sectors based on Nace code

Industries	Nace	Definitions
Food	15-16	Manufacture of food, beverage and tobacco
Textile	17-19	Manufacture of textiles ; Manufacture of wearing apparel; dressing and dyeing of fur ; Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
Wood	20-22	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials ; Manufacture of pulp, paper and paper products
Chemicals	23-24	Manufacture of coke, refined petroleum products and nuclear fuel ; Manufacture of chemicals and chemical products ; Publishing, printing and reproduction of recorded media
Plastic Rubber	25	Manufacture of rubber and plastic products
Non-metallic	26	Manufacture of other non-metallic mineral products
Basic metal	27-28	Manufacture of basic metals ; Manufacture of fabricated metal products, except machinery and equipment
Machinery	29	Manufacture of machinery and equipment n.e.c
Electrical	30-33	Manufacture of office machinery and computers ; Manufacture of electrical machinery and apparatus n.e.c.; Manufacture of radio, television and communication equipment and apparatus ; Manufacture of medical, precision and optical instruments, watches and clocks
Vehicles	34-35	Manufacture of motor vehicles, trailers and semi-trailers ; Manufacture of other transport equipment
n.e.c	36	Manufacture of furniture; manufacturing n.e.c.

Appendix B : Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1-Innovative performance	1																		
2-Group	-0,01	1																	
3-Size	0,01	0,45	1																
4-European markets	0,01	0,17	0,20	1															
5-International markets	0,05	0,14	0,21	0,53	1														
6-Internal R&D	0,06	-0,02	0,02	0,06	0,103	1													
7-External R&D	0,00	0,04	0,02	0,03	0,042	0,14	1												
8-Coop_university	0,06	0,15	0,30	0,13	0,161	0,14	0,03	1											
9-Vehicles	0,02	-0,01	0,03	0,02	-0,005	0,02	0,01	-0,02	1										
10-Machinery	-0,02	0,05	0,05	0,05	0,120	-0,02	-0,01	0,02	-0,11	1									
11-Chemicals	-0,01	0,07	0,04	0,05	0,090	0,02	0,04	0,14	-0,12	-0,12	1								
12-Electrical	-0,01	-0,01	-0,05	0,02	0,079	0,20	0,02	0,05	-0,15	-0,15	-0,17	1							
13-Food	-0,08	0,01	0,02	0,00	-0,109	-0,09	-0,02	-0,05	-0,13	-0,13	-0,14	-0,18	1						
14-Textile	0,11	-0,13	-0,15	-0,05	-0,023	0,02	0,03	-0,06	-0,09	-0,09	-0,10	-0,12	-0,10	1					
15-Wood	-0,03	-0,01	-0,03	-0,06	-0,089	-0,06	-0,03	-0,06	-0,09	-0,09	-0,10	-0,13	-0,11	-0,07	1				
16-plastic Rubber	0,06	0,05	0,01	0,02	-0,007	-0,05	-0,02	-0,02	-0,09	-0,09	-0,10	-0,12	-0,10	-0,07	-0,07	1			
17-Non metallic	-0,01	0,01	0,03	-0,08	-0,059	-0,04	-0,01	-0,02	-0,07	-0,07	-0,08	-0,10	-0,09	-0,06	-0,06	-0,06	1		
18-Basic metals	-0,01	0,00	0,05	0,01	-0,022	-0,06	-0,03	0,01	-0,10	-0,11	-0,12	-0,15	-0,13	-0,08	-0,09	-0,08	-0,07	1	
19-N.E.C	-0,01	-0,08	-0,03	-0,06	-0,037	-0,02	0,03	-0,06	-0,06	-0,07	-0,07	-0,09	-0,08	-0,05	-0,05	-0,05	-0,04	-0,06	1

Appendix C: regression of university cooperation

Variable	Coef.	t
Investment tax credit	0,146***	7
Group	-0,003	-0,18
Size	0,058***	8,62
European market	0,027	1,4
International market	0,011	0,56
Vehicles	-0,025	-0,66
Chemicals	0,051	1,27
Electrical	0,026	0,67
Food	-0,022	-0,57
Textile	-0,024	-0,57
Wood	-0,029	-0,71
Plastic Rubber	0,001	0,02
Non metallic	-0,029	-0,82
Basic metals	-0,061**	-1,78
NEC	-0,050	-1,27
Constant	-0,183***	-4,15