Public and Private Funding of Academic Laboratories : Crowding out Evidence from a Large European Research University

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Abstract : Crowding out of public funding on private support to non-profit institutions has been predicted and observed while crowding in has been recorded for universities. Is the academe a Realm of complementarity between funding sources while the opposite prevails elsewhere ? The present paper challenges this issue relying on an original panel of laboratories (rather than universities) of a large European research university. The theoretical model endogeneizes the laboratory allocation of staff efforts to research and to fund raising from public and private sources. It predicts a mutual crowding out between public and private funding which is confirmed by our estimation results.

Keywords : Funding ; Academic Laboratories ; Panel Data ; Crowding.

JEL classification : C33 ; L30 ; H4 ; O31

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1 Introduction

The last two decades have been a disruptive context for academic research funding : Shortening of public funding, evolving rationales and changing regulatory environments. One of the crucial issues relates to the rising share of public research being funded by private firms through contractual relations. In the burgeoning field of the Economics of Science (Dasgupta and David, 1994 ; Stephan, 1996 ; Diamond 1996), scholars mainly focused their attention on the consequences of this phenomenon on research production : Possible benefits are an increase of academic research due to such extra funding and a shift in its economic relevance. Risks reside in a slowing down in the dissemination of findings, a shift toward applied research and a decrease of research productivity[1].

The present paper adopts a slightly different aim by focusing on the determinants of funding itself : What stimulates the attractiveness of academic research for both private and public contractual funding[2] ? The main issue we address is whether public and private financial supports to academic research crowd in or crowd out mutually ? This should document the ability of academic research institutions to sustain connections with both public and private fund providers. Thereby, we meet another wide and recently active literature which aims at understanding how public funding impacts on private donations to non-profit institutions. On the one hand, this literature provides a general crowding out prediction both from theoretical models and from econometric tests performed on US charities (Sugden, 1982 ; Andreoni, 1990, Andreoni and Payne 2003)[3]. On the other hand, Payne (2001)[4] finds that federal public research funding increases private donations to Ph.D. granting US universities. Her theoretical model stresses a "spillover" effect of federal public funding on private donations. She argues that private and public funds may be used in different but complementary ways and/or that public funding may signal to private donors the quality of the research institution given the extensive review and

[1] For some empirical evidence see Cohen et al. (1998), Blumenthal et al. (1996) and Thursby and Thursby (2000).

[2] Contractual funding here designates all funds received on a contractual basis, including grants. It includes all funds collected from private sources. The remaining funds are the 'recurrent' public funds regularly allocated by national authorities on a non-competitive basis. In France it includes wages of permanent scholars and researchers and of most of the technical and administrative staff.

[3] Basic models in that literature focused on the giver's objective function. The giver ranges from a 'public good philanthropist' (Sugden, 1982) to the so called 'warm-glow philanthropist' (Andreoni, 1990). The former agent aims to contribute to the production of a public good while the latter 'likes' giving a certain amount without directly caring about the quantity of public good produced. The literature also analysed the other side of the coin, that is charities' strategies. A recent contribution to that issue is the one of Andreoni and Payne (2003) who built a fund raising model in which heterogenous donors give when they are asked by charities which support fund raising costs. The models of the two types predict crowding out of public funding on private support : because of a decrease of the donations for the first type of models (from zero to equivalent) and because of a decrease in fund raising efforts in the second type.

[4] We should also mention Connolly (1997) who studies the relation between internal and external support to research on a panel of US universities. External research funding is found to have a positive effect on future levels of internal support and reciprocally internal support sustains external funding.

monitoring undertaken by agencies[5].

Are academic research institutions subject to a specific complementarity in collecting funds from public and private sources while crowding out would apply to other non profit institutions ? The paper challenges that statement in adopting a different approach. The main originality of our study resides in that it is micro-based, i.e. conduced at the research laboratory level while Connolly (1997) and Payne (2003) focus on the university level of investigation. As it has been emphasized, the laboratory is a relevant level for analyzing scientific activity in the Continental Europe style of academic research organization (Stephan, 1996) and certainly when funding issues are addressed (Crow and Bozeman, 1987 ; Arora et al. 1998)[6].

Focusing on a more disaggregated level of analysis allows us to specifically study agents' strategies. Principal Investigators and lab directors often complain of the time they spend to obtain research grants or contracts. They have to solve organizational problems such as how to allocate their time between fund raising from different sources and research activities. In this paper, we present a simple theoretical model designed to study how these behaviors affect funds collection from public and private sources. It introduces weak assumptions on fund providers' behavior and thus encompasses various funding relations such as grants and sponsored research. We shall designate all funds received through such relations as *contractual funds*. The model predicts a mutual crowding out due to opposite endogenous responses to shocks affecting fund-raising.

These predictions are confirmed by our econometric estimations realized on an original panel dataset over the period 1993-2000 of 76 laboratories which belong to one single university, namely Louis Pasteur University (ULP) of Strasbourg. This university has a large research capacity and has an old tradition of fundamental research and a long standing of scientific excellence. It belongs to the top-fifteen European research universities (European Report on Science and Technology Indicators, 2003). We use instrumental variable methods introduced by Hausman and Taylor (1981) and Amemiya and Macurdy (1986) which allow us to deal with the endogeneity of some time variant and time invariant explanatory variables.

The next section presents the theoretical model. The third section presents the data. The fourth section details the empirical model and the fifth presents the results. The last section concludes.

[5] This statement is consistent with the sequential fund raising model introduced by Vesterlund (2003). She shows that when there is imperfect information on the value of the public good and when contributors can purchase information on the quality of the public good, there exists an announcement equilibrium : The high quality charity has an incentive to reveal previous fundings to obtain more.

[6] Therefore it is not surprising that in the French research system (as well as in several other European countries) the amounts collected are administratively allocated to labs and then managed internally. In such systems the research laboratory is thus most diaggregated level attainable to analyse funding whereas the Principal Investigator would be more relevant for studying funding in US Universities.

2 Theoretical model

Let us consider a public laboratory[7] which produces a research output R according to the simple following production function :

$$R = \delta f(\alpha x + \beta y) h(r), \quad (1)$$

with r the research effort, x the amount of funds received from public sources and y the funds received from private sources. Strictly positive parameters α and β allow the two sources of funds to have different productivities[8]. Thus $\alpha x+\beta y$ is the total amount of funds corrected for intrinsic productivities. The strictly positive parameter δ gives the quality of the laboratory considered. The research outcome R is simply assumed to be the product of quality δ, of a function $f(\cdot)$ of the corrected amount of funds used and of a function $h(\cdot)$ of research effort. The functions $h(\cdot)$ and $f(\cdot)$ are assumed to be continuous, twice differentiable, increasing and weakly concave over $\Re^+$ $(h'(u) > 0,\ f'(u) > 0, h''(u) \leq 0, f''(u) \leq 0, \forall u \geq 0)$[9].

The lab can dedicate some of its effort (or time) to raising public funds. Let θ be that amount. For the sake of simplicity we assume that

$$x = x(\theta; \delta, \varphi). \quad (2)$$

The amount of public funds received is a function of the effort dedicated to raising public funds and of parameters δ (the lab quality) and φ the relative availability of public funds. We assume x to increase in a weakly concave manner with θ $(\partial x/\partial\theta > 0, \partial^2 x/\partial\theta^2 \leq 0)$. The public fund managers are more likely to fund public laboratories when they are more solicited but the marginal returns of fund raising efforts are decreasing. x is assumed to increase strictly with quality δ while the productivity of fund raising effort increases weakly with δ $(\partial x/\partial\delta > 0, \partial^2 x/\partial\theta\partial\delta \geq 0)$. Since we intend φ to measure the easiness of public fund raising activity, we assume that $\partial x/\partial\varphi > 0$. Finally we further assume that this impact increases with public funds raising effort such that $\partial^2 x/\partial\varphi\partial\theta > 0$.

There is a continuum of potential private fund providers uniformly distributed over the line segment $[0, \bar{e}]$ which stands for the space state of research interests. The lab considered is by convention located at 0. Let $a \in [0, \bar{e}]$ be the address of a private fund provider. Since the lab is located at zero, a is also the distance between the private fund provider's research interests and the lab research issues. The lab can spend some effort e raising private funds. It gets in touch with each firm located at an address a such that $a \leq e$. $\bar{e}$ is assumed to be large enough, such that $e < \bar{e}$. When contacted, the private fund provider gives the non null

[7] The agent considered here is indifferently the laboratory or the laboratory manager. We do not discuss here the relation between the lab manager and other permanent scholars, i.e. the lab is assumed to be a team. This agent could also be a Principal Investigator in the typical organization of US academic research.

[8] Usually scientists tend to consider that $\alpha \geq \beta$, that is they make a better use of public funds because private ones are often associated with specific constraints or counterparts.

[9] Unlike Payne (2001), we do not assume any ad hoc complementarity between the funds of different sources. Here public and private funds are substitutes (potentially not in an equal proportion).

amount $\int_a^{a+da} p(u,\eta)\,du = p(a,\eta)$ to the lab. The function $p(a,\eta)$ is increasing with parameter η which indicates the propensity of solicited potential private funds providers to fund the lab (by definition $\partial p(a,\eta)/\partial\eta > 0$). Moreover, it is assumed that the closer the fund providers' research interests to the lab's ones, the more they are inclined to fund the lab ($\partial p(a,\eta)/\partial a \leq 0$). The private funds collected by the lab are given by :

$$y(e;\eta) = \int_0^e p(u,\eta)\,du \tag{3}$$

which is such that $\partial y/\partial\eta > 0$, $\partial y/\partial e = p(e,\eta) > 0$ (when $e > 0$) and $\partial^2 y/\partial e\partial\eta = \partial p(e,\eta)/\partial\eta > 0$.

The lab manager sets up his strategy by choosing the allocation of the time of his research personnel (including his own) between the three main tasks (raising public funds, raising private funds or research) so as to maximize the research outcome R. His programme is given by :

$$\max_{e,\theta,r} \delta f(\alpha x(\theta;\delta,\varphi) + \beta y(e;\eta))\, h(r) \tag{4}$$

under the time constraint $e + \theta + r = 1$, the total available time being normalized to the unity. Solving this programme is straightforward and gives us two conditions obtained by recombining the FOCs. The first one is :

$$\alpha x'_\theta(\theta;\delta,\varphi) = \beta y'_e(e;\eta). \tag{5}$$

It stresses that the lab sets the level of effort dedicated to collecting private and public funds such that both have the same marginal returns on research production. Note that this is independent of the research effort level r. The second condition is :

$$\alpha x'_\theta(\theta;\delta,\varphi)\, f'(\alpha x(\theta;\delta,\varphi) + \beta y(e;\eta))\, h(r) = h'(r)\, f(\alpha x(\theta;\delta,\varphi) + \beta y(e;\eta)). \tag{6}$$

It states that the marginal productivity of fund raising effort on the research outcome should also equal the marginal research productivity of research effort r [10].

Equations (5), (6) and the time constraint define an optimal solution (e^*, θ^*, r^*) which gives the optimal amount of funds collected (x^*, y^*). Comparative statics allow us to describe the impact of a shock on the productivity of public fund raising activity. The following lemma states the reaction of the laboratory.

Lemma 1. *If the lab encounters a positive (negative) shock on the productivity of public fund raising (φ) it decreases (increases) the effort dedicated to private fund raising (e).*

Proof. See Appendix A.

Let us now consider a shock in the availability of private fund raising, that is if suddenly η moves to η'. Lemma 2 below states labs reactions to such shocks.

Lemma 2. *If the lab encounters a positive (negative) shock on the productivity of private fund raising then it decreases (increases) the effort dedicated to public fund raising (θ).*

[10] Here, we focus on public funds. Nevertheless, similar statements apply to private fund raising since equation (6) could be simply rearranged accordingly by using equation (5).

Proof. Similar to the proof of Lemma 1.□

Let us now wonder how variations in the availability of funds from different sources may affect the amounts collected. The following proposition introduces a general crowding out statement.

Proposition 1. *Shocks on the availability of one of the sources of funds have opposite impacts on the amounts of funds received from public and private sources.*

Proof. From Lemma 1 and Lemma 2 we know that a positive (negative) shock on the productivity of one source of funding leads to a non-decrease (non-increase) of efforts dedicated to collecting the funds from that source while effort dedicated to collecting funds from the other source decrease (increase). This trivially leads the funds collected from the former source to increase (decrease) while the amount obtained from the other source decreases (increase). Therefore, funds collected should vary in opposite manners in reaction to such shocks. □

Thus the theoretical model predicts that shocks on the availability of funds should provoke crowding out between sources of funding due to endogenous reactions of laboratories. The rationale behind this effect is the following. If a lab obtains suddenly funds more easily from one of the two sources, due to for instance his director being introduced to networks of key players, it is likely to reduce its staff's effort spent in collecting funds from the other source of funds in order to maximize its research output. Efforts are then worthily dedicated to research performing and/or to exploiting relatively more the source of funds which becomes more easier to mobilize.

Proposition 2 states how the other parameters present in programme (4) affect fund raising.

Proposition 2. *A positive (negative) shock on the quality of the lab (δ), a positive (negative) shock of the research productivity of public funds (α) and a negative (positive) variation of the productivity of private funds (β) increase (decrease) the funds received from public sources and decrease (increase) the funds received from private sources.*

Proof. δ and α intervene in equations (5) and (6) exactly as φ while β intervenes just as η. Therefore they have the same impacts on x^* and y^* than φ and η do. The latter impacts are given in Lemma 1 and Lemma 2. The proposition follows.□

3 The Dataset

The data come from the Louis Pasteur University (ULP) in Strasbourg (France) which is a quite large and diversified university. It comprises seventeen separate institutional components (i.e. schools, education/training and research units, and various institutes) located in six campuses in the Strasbourg area which count nearly 20,000 students. Research and teaching at the university cover a wide range of disciplines. These disciplines exclude humanities and social sciences (except economics, management and geography). ULP has an old tradition of fundamental research and a long standing of scientific excellence. Its researchers have received numerous national and international scientific prizes, including several Nobel Prizes[11]. The

[11] ULP researchers have received numerous scientific prizes (six Nobel prices and one Field Medal). Active researchers count one Nobel laureate, eleven members of the Institut Universitaire de France and eleven members of the National Academy of Science.

Third European Report on Science and Technology Indicators (2003, p.311) ranks it first among French universities in terms of impact, and 11th among European universities. Overall, ULP is one of the largest French universities in terms of research capacities. The university research capacities are reinforced by a close-knit with major national research bodies such as CNRS[12] and INSERM[13].

The laboratories of the university undergo every four years an evaluation process which is necessary to be recognized and supported by the Ministry of Education and Research[14], the CNRS and INSERM. We collected information from the administrative reports completed for the 1996 contractual affiliation round. After the cleaning process, 76 distinct laboratories for which we have complete and reliable information remain from an initial sample of 83 labs. In the case of ULP, the database includes almost all the existing research units at the university and the great majority of available teaching and research staff. Such evaluation round occurs every four years and the report constitutes a *précis* of the past four years and a project for the next four ones. Therefore information collected in these documents concern the whole 1993-2000 period.

All reports contain standardized information which is especially precise and reliable as regard the staff of the labs for each detailed category of personnel. It also provides individual information on each permanent scholar and each permanent researcher (including name, sex, age and status)[15]. In France permanent research staff may occupy two types of positions : Either a university type position (with teaching and research duties) or a full-time research position. The former belong to the university while the latter are employed by the large national public research organizations such as CNRS or INSERM. Nevertheless both categories work together in university labs. In addition, for both categories, there is a clear promotion (from Assistant Professor to Full Professor and from Researcher to Director of Research) on the basis of scientific accomplishments and seniority. Such a promotion does not imply tenure since, in France, Assistant Professors and Researchers are tenured from the very beginning of their careers. Still, promotion implies a significant increase in income and social status within the academic sphere.

The remaining data come from three original datasets that were matched at the laboratory level. The first one concerns funding, the second publications and the third one patenting. Information on labs contractual funding comes from the two Technology Transfer Offices of the university campus. Fund received have to be reported in a formalized manner to one of these offices. This is why it is designated as contractual funding whether it explicitly implies a counterpart or if it is a grant. After a long cleaning and harmonization work, we were able to know for each contract the year it was signed and started, the duration, the amount of the monetary transfer to the university and the lab which was the beneficiary of this amount.

[12] National Institute for Scientific Research.

[13] National Institute for Health and Medical Research.

[14] The ministry also provides at this occasion the right of PhD supervision.

[15] These variables are not available year by year and will be treated as time-invariant. This assumption can be appreciated as acceptable since there is usually a very low turnover in teaching and research staff.

Since we know also the contractors (the fund providers), we were able to decompose the funds according to the sources of funding, i.e. to distinguish public and private contractors.

The publication records of all permanent scholars were also collected using SCI (Science Citation Index) and SSCI (Social Science Citation Index) databases produced by the Institute for Scientific Information (ISI). More than 26,000 publication occurrences were recorded over the 1993-2000 period. By dividing each occurrence by the number of coauthors we obtain a normalized scientific contribution of each author considered. Each publication item is also associated with the impact factor of the review in which it was published given in the JCR (Journal Citation Report) database produced by ISI. That information gives the opportunity to correct publication performance for impact. By summing individual productions for each laboratory we were able to establish the yearly publication outcome of each lab.

The patent data come from the French Institute of Intellectual Property (INPI). We matched our list of permanent researchers with all inventors appearing in French, European and world patent applications[16,17]. The problem is that this set includes double counts since one application can appear through different channels. Therefore, we identified patent families which are defined by a unique priority number. For this study we use *epo-wo* patent families that we define as the set of patents that have the same priority number and have at least one occurrence of a European or a world patent application. We found 229 of such patent application families that were allocated to our labs for each given year according to the priority date.

4 Methodology and empirical specifications

The dependent variables will be either $PUBF_{(it)}$ or $PRIVF_{(it)}$, the amount of funds collected from public and private sources respectively, the attribution decision of which has been made on year t for laboratory i. We do not test directly the effects of the one on the other. We are more interested in the effects of the availability of funds from one source on the capacity and willingness to collect funds from the other source. Therefore two more variables that spread differently funds received over time are built. The information on the duration (in months) of each contract is used to allocate uniformly the amounts received over the period mentioned from the beginning of the year it was signed[18]. Funds are again distinguished according to the source they were collected from. $FLOWPUB_{(it)}$ and $FLOWPR_{(it)}$ characterize the flows of currently available amount of funds at year t obtained from public and private sources respectively. We are thus able to estimate the impact of the availability of funds collected from one source on the

[16] In Europe the invention activity of universities as observed through the patents owned by univerties is often underestimated because it unduely assumes that the research institutions are among the owners (the applicants in the European system) of the patents that their personnel contributed to invent.

[17] It should be mentioned that we miss all patents applied for in other countries than France, which did not use the EPO procedure in the first place and which were never extended to France. We are inclined to think that this set of patents is likely to be very limited.

[18] This variable makes use of information on contracts signed before year 1993 and which spread over the time window considered. It was built thanks to the availability of reliable information on funds since year 1985.

arrival of funds from the other source.

To sum up, for each laboratory i, we have eight annual observations on the following time-variant variables[19] : the amount of funds collected from public sources ($PUBF_{(it)}$), the amount of funds collected from private sources ($PRIVF_{(it)}$), the currently available amount of funds obtained from public sources ($FLOWPUB_{(it)}$), the currently available amount of funds obtained from private sources ($FLOWPR_{(it)}$), publication performance corrected for impact and coauthorship ($PIMP_{(it)}$), dummy for coauthorship with at least one researchers employed abroad ($INTER_{(it)}$), dummy for coauthorship with at least one researcher in industry ($INDUS_{(it)}$), the number of patent families invented ($PAT_{(it)}$), the average age of permanent professors and researchers ($AGE_{(it)}$). Time-invariant variables relate to the personnel employed in the laboratory : the number of permanent professors or researchers ($SIZE_i$), the share of promoted among assistant professors and researchers ($PROMO_{(i)}$), the share of full-time researchers among permanent professors or researchers ($FTIME_{(i)}$), the share of females among permanent professors or researchers ($GENDER_{(i)}$), the number of Ph.D. students ($PHD_{(i)}$), the number of non researchers (administrative personnel, technicians and engineers) ($NONRES_{(i)}$), the number of national ($NPOST_{(i)}$) and foreign post-docs ($FPOST_{(i)}$).

The model that we consider is :

$$Y_{it} = X_{1it}\beta_1 + X_{2it}\beta_2 + Z_{1i}\gamma_1 + Z_{2i}\gamma_2 + \alpha_i + \varepsilon_{it}, \tag{7}$$

where $i = 1, 2, \ldots, 76$, and $t = 1, 2, \ldots 8$. Combining all 608 observations, we can write (7) as follows :

$$Y = X\beta + Z\gamma + \alpha + \varepsilon, \tag{8}$$

where $X = (X_1 : X_2)$, $Z = (Z_1 : Z_2)$, ε_{it} are *iid* $N(0, \sigma_\varepsilon^2)$ uncorrelated with both the explanatory variables X_{it} and Z_i. We assume that the individual effects α_i are *iid* $N(0, \sigma_\alpha^2)$. Let $W = I_{TN} - B$ and $B = I_N \otimes (1/T)V_T V_T'$ the within and between operator respectively, where V_T denotes a T vector of ones.

Asymptotically, if we assume that X and Z are uncorrelated with α, Generalized Least Squares yield efficient estimates of the parameters β and γ. This estimator can be obtained by Ordinary Least Squares from

$$\Omega^{-\frac{1}{2}}Y = \Omega^{-\frac{1}{2}}X\beta + \Omega^{-\frac{1}{2}}Z\gamma + \Omega^{-\frac{1}{2}}\alpha + \Omega^{-\frac{1}{2}}\varepsilon, \tag{9}$$

where $\Omega = cov(\alpha + \varepsilon)$ is the $TN \times TN$ variance-covariance matrix where $\Omega^{-\frac{1}{2}} = I_{TN} - (1-\theta)B$ and $(\theta)^2 = \sigma_\varepsilon^2/(\sigma_\varepsilon^2 + T\sigma_\alpha^2)$. The feasible GLS estimator is given by the expression

$$\hat{\Upsilon}_{GLS} = (\Delta'\hat{\Omega}^{-1}\Delta)^{-1}\Delta\hat{\Omega}^{-1}Y, \tag{10}$$

where $\hat{\Upsilon}'_{GLS} = \left(\hat{\beta}', \hat{\alpha}'\right)_{GLS}$, $\Delta = (X : Z)$ and $\hat{\Omega}^{-1}$ is a consistent estimator of Ω^{-1}.

However, if we assume, following Hausman and Taylor (1981) - hereafter HT -, Amemiya and MacCurdy (1986) - hereafter AM - that the individual effects α_i are correlated with X_{2it}

[19] All monetary amounts are in thousand euros.

and Z_{2i} but uncorrelated with X_{1it} and Z_{1it}, efficient estimates for β and γ can be obtained by the Instrumental Variable procedures proposed by HT, AM. This estimator is given by

$$\hat{\Upsilon}_{IV} = (\Delta'\hat{\Omega}^{-\frac{1}{2}}P_M\hat{\Omega}^{-\frac{1}{2}}\Delta)\Delta'\hat{\Omega}^{-\frac{1}{2}}P_M\hat{\Omega}^{-\frac{1}{2}}Y, \tag{11}$$

where $\hat{\Upsilon}'_{IV} = \left(\hat{\beta}', \hat{\alpha}'\right)_{IV}$, M is the matrix of instruments and $P_M = M(M'M)^{-1}M'$. For instance, HT recommend an instrument matrix $M_{HT} = (WX_1 : WX_2 : BX_1 : Z_1)$. The HT procedure uses the within variation in X_1 as instruments for X_2 and the between variation in X_1 as instruments for Z_2. While HT use each X_1 as two instruments, AM use each of these variables as $(T+1)$ instruments namely $(WX_1 : X_1^*)$ where each column of X_1^* contains the X_1 variables for a single time period. In fact, HT require only the means of the variables in X_1 to be uncorrelated with the effects, whereas AM require uncorrelatedness at each point of time.

5 Estimation results

In Table 1 for both the dependent variables $PRIVF$ (columns 1 and 2) and $PUBF$ (columns 4 and 5) we consider, first, the conventional procedures Within and GLS estimates. The Within estimates are unbiased and consistent whether or not the effects α_i are correlated with the explanatory variables[20]. However the GLS estimates are biased and inconsistent if the individual effects are correlated with some explanatory variables. The assumption that α_i are uncorrelated with (X, Z) is rejected by a Hausman test based on the difference between the GLS and Within estimates. The Hausman test are $\chi^2_{(5)} = 50.28$ (for the dependent variable $PRIVF$) and $\chi^2_{(5)} = 21.58$ (for the dependent variable $PUBF$) which are significant at 1 per cent level. The IV estimates are presented in columns 3 and 6[21]. In the regressions we let : $X_1 = (INDUS, INTER, PAT, AGE)$, $Z_1 = (SIZE, FTIME, PROMO, NONRES, GENDER)$, $Z_2 = (NPOST, FPOST, PHD)$. Only X_2 changes with the dependent variable : when Y_{it} is $PUBF_{it}$, X_2 is $(FLOWPRIV, PIMP)$ and when Y_{it} is $PRIVF_{it}$, X_2 is $(FLOWPUB, PIMP)$. The set of instruments proposed by AM is legitimate and supported by a Hausman test of the difference between the HT estimator and the AM estimator[22]. These tests are $\chi^2_{(13)} = 3.86$ (for the dependent variable $PRIVF$) and $\chi^2_{(13)} = 0.96$ (for the dependent variable $PUBF$) which are both insignificant at five per cent level.

– Table 1 about here –

The main result consists in the negative and significant effects of $FLOWPR_{(it)}$ on $PUBF_{(it)}$ and of $FLOWPUB_{(it)}$ on $PRIVF_{(it)}$ (for the two AM regressions as well as in all estimations reported in Table 1). The arrival of funds from one source is negatively affected by the availability of funds from the other source. Since we control for the unobserved individual effects and their potential correlation with time variant and time invariant regressors, the empirical study

[20] All time-invariant variables are eliminated by the data transformation.
[21] The IV estimates presented here are based on the set of instruments proposed by AM.
[22] Several alternative sets of X_1 and Z_1 were tried.

therefore supports the idea that a mutual crowding out phenomenon is at play between both sources of funds as predicted in Proposition 1. When the lab experiences a higher inflow of funds from one source, its propensity to collect funds from the other source decreases.

The second most important result of our study is that publication performance has a positive impact on public funds arrival and a negative one on private funds. This result is consistent with Proposition 2. If (as it is specified in equation (2)) the willingness of public fund providers to fund a lab increases with research quality (δ) signals, lab managers who have good records are likely to concentrate efforts to raising funds from public sources. When they have weaker records they turn preferentially toward private sources. This explanation relies on the assumption that private funds managers do not take publication signals into consideration[23]. A complementary explanation would be that faculty prefer public funds because private funds are more connected to the realization of research purposes they are less interested in[24]. If best labs have a higher capacity to attract public funds, they have a higher opportunity cost to put efforts in raising private funds. Less reputed labs will accept more easily to dedicate more time and effort to private fund raising.

The remaining significant effects recorded are the following. The average age of permanent scholars increases funding from both sources. Age may proxy experience in collecting funds and/or personal relationships with potential fund providers built over time. Another explanation would be that older scholars, who have lower incentives to publish, may spend a higher share of their time in fund raising given that they are also more evaluated on the basis of their ability to attract financial support. National and foreign post-docs increase private fund arrival while the Ph.D. students increase public funding. Post-docs provide the specialized advanced knowledge private companies are often interested in. Ph.D. students are usually associated to contracts or grants running over larger periods of time (mostly 3 years) which deal with more fundamental topics that public sources are more likely to support. For instance Ph.D. students are often associated to research projects funded by the European Commission. Non researchers (engineers and administrative staff) increase the attraction of public funds and have no significant impact on private ones[25].

6 Conclusion

In this paper we study the yearly arrival of contractual funding of academic laboratories from public and private sources. Our theoretical model stresses lab managers that allocate efforts between research purposes and fund raising from public and private sources. It predicts mutual

[23] This assumption is the one of our theoretical model. We could allow private fund managers to also take quality signals into consideration. Then it could easily be shown that the theoretical prediction still holds if they value it less than public fund managers.

[24] As regard to the theoretical model, this explanation simply builds upon the idea that α and δ are likely to be correlated in the reality.

[25] Like permanent scholars, these staff are formally employed (and paid) directly by the national bodies or the ministry of research.

crowding out between public and private funding. The empirical part of the paper performed on a panel dataset of labs confirms that the available amounts of funds from one source crowd out the amounts of funds collected from the other source. These results do not formally contradict the crowding in result previously obtained for universities : the issue of the allocation of scholars' time between research and fund raising tasks may be prominent only at the disaggregated lab level and not significant at the university level. The second result is that publication counts decrease private funding while it increases public support.

These two results somehow stress a fairly pessimistic conclusion as regard the ability of academic labs to simultaneously sustain funding from both public and private sources and, to associate good publication records and connections with private fund providers (mainly industry). However the theoretical model stresses a rationale for explaining such difficulties which would suggest that the costs of fund raising efforts should be lowered by increasing institutional (and administrative) support to such tasks. A national and institutional bias may prevent from generalizing our results since our data concern only labs affiliated to a French university. Nevertheless, the theoretical model can adapt to various research organizations, and we are in search of comparable empirical studies on data collected in other countries that might be compared to ours'.

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8 References

Amemiya, T., Macurdy, T.E., 1986. Instrumental-variable estimation of an error-component model. Econometrica 54, 869-880.

Andreoni, J, 1990. Impure altruim and donations to public goods : a theory of warm-glow giving. Economic Journal 100, 464-477.

Andreoni J, Payne, A., 2003. Do government grants to private charities crowd out giving or funding ?. American Economic Review 93, 792-812.

Arora, A., David, P.A., Gambardella, A., 1998. Reputation and competence in publicly funded science : Estimating the effects on research group productivity. Annales d'Economie et de Statistique 49/50, 163-198.

Blumenthal, M.D., Causino, N., Campbell, E.G., Louis, K.S., 1996. Participation of life-science faculty in research relationships with industry. The New England Journal of Medicine 335, 1734-1739.

Carayol, N., 2003. Objectives, agreements and matching in science industry collaborations : Reassembling the pieces of the puzzle. Research Policy 32, 887-908.

Cohen, W.M., Florida, R., Randazzese, L., Walsh, J., 1998. Industry and the academy : Uneasy partners in the cause of technological advance. In : R. Noll, ed., Challenge to the University, (Brookings Institution Press, Washington DC) 171-199.

Connolly, L.S., 1997. Does external funding of academic research crowd out institutional support. Journal of public Economics 64, 389-406.

Crow, M., Bozeman, B., 1987. R&D laboratory classification and public policy : The effects of environmental context on laboratory behavior. Research policy 16, 229-258.

Dasgupta, P., David, P.A., 1994. Toward a new economics of science. Research Policy 23, 487-521.

Duncan, B., 2004. A theory of Impact philantropy. Journal of Public Economics 88, 2159-2180.

Hausman, J.A., 1978. Specification tests in econometrics. Econometrica 46, 1251-1272.

Hausman, J.A., Taylor, W.E., 1981. Panel data and unobservable individual effects. Econometrica 49, 1377-1398.

Payne, A., 1998. Does the government crowd-out private donations ? New evidence from a sample of non-profit firms. Journal of Public Economics 69, 323-345.

Payne, A., 2001. Measuring the effect of federal research funding on private donations at research universities : Is federal research funding more than a substitute for private donations ?. International Tax and Public Finance 8, 731-751.

Rose-Ackerman, S., 1982. Charitable giving and "excessive" fundraising. The Quarterly Journal of Economics 97, 193-212.

Stephan, P.E., 1996. The economics of science. Journal of Economic Literature 34, 1199-1235.

Thursby, J., Thursby, M., 2000. Who is selling the Ivory Tower ? Sources of growth in university licensing. National Bureau of Economic Research, no. 7718.

9 Appendix A

Proof of Lemma 1.

We first consider a positive shock of public fund raising activity : that is, if suddenly φ increases up to say $\varphi' > \varphi$. By assumption, we know that $\partial^2 x/\partial\theta\partial\varphi > 0$. Therefore, an increase in φ increases the left hand side of equation (5) . The lab can react to the instability that occurs in that equation changing either θ, e or the two of them (equation (5) is independent of r). The two potential reactions are : i) keeping e constant and increasing θ (since x is concave with θ, an increase in θ should reduce the left term of 5), ii) decreasing e (since y is concave with e, an increase in e should reduce the right term of 5) while keeping θ constant or having it increasing (left term increases and right term decreases).

Let us now see if these two cases are compatible with equation (6) and time constraint $e + \theta + r = 1$. To do so let us integrate the constraint in equation (6) which becomes after a few algebraic manipulations :

$$\alpha x_{\theta}'(\theta,\delta,\varphi)=\frac{h'(1-\theta-e)}{h(1-\theta-e)}\Bigg/\frac{f'[\alpha x(\theta;\delta,\varphi)+\beta y(e;\eta)]}{f[\alpha x(\theta;\delta,\varphi)+\beta y(e;\eta)]} \tag{A1}$$

In case i) one should have from equation (5) that $\alpha x_{\theta}'(\theta;\delta,\varphi)$ remains constant. Nevertheless, it is easy to show that in case i) the right term of equation $(A1)$ would not remains constant. Indeed, an increase in θ would simultaneously increase its numerator and decrease its denominator. This is due to the fact that both $f(\cdot)$ and $h(\cdot)$ are increasing and weakly concave, which lets $h'(x)/h(x)$ and $f'(x)/f(x)$ decrease with x, while $(1-\theta-e)$ decreases (θ increases and e stays unchanged or increases) and the total funds received should increase (because both θ and φ increase). Thus only case ii) is compatible with the agent's maximization program, which implies a decrease in e.

If the shock on public funding availability is negative (φ decreases to $\varphi''<\varphi$), then a symmetric reasoning applies and it results in the lab decreasing e. □

10 Maximization : Details for the referees/ Not for publication !

The Lagrangian can be written as follows :

$L=R-\lambda[1-(e+\theta+r)]$

FOC are the following :
$\frac{\partial L}{\partial\theta}=0\rightarrow\delta\alpha x_{\theta}'(\theta,\delta,\varphi)f'(\alpha x(\theta;\delta,\varphi)+\beta y(e;\eta))h(r)=-\lambda$
$\frac{\partial L}{\partial e}=0\rightarrow\delta\beta y_{e}'(e;\eta)f'(\alpha x(\theta;\delta,\varphi)+\beta y(e;\eta))h(r)=-\lambda$
$\frac{\partial L}{\partial r}=0\rightarrow\delta f(\alpha x(\theta;\delta,\varphi)+\beta y(e;\eta))h'(r)=-\lambda$
$\frac{\partial L}{\partial\lambda}=0\rightarrow 1=e+\theta+r$

Combining first and second FOC yields :
$\delta\alpha x_{\theta}'(\theta;\delta,\varphi)f'(\alpha x(\theta;\delta,\varphi)+\beta y(e;\eta))h(r)=\delta\beta y_{e}'(e;\eta)f'(\alpha x(\theta;\delta,\varphi)+\beta y(e;\eta))h(r)$

$$\alpha x_{\theta}'(\theta;\delta,\varphi)=\beta y_{e}'(e;\eta)$$

given in equation (5) .

Combining second and third FOC yields :
$\delta\alpha x_{\theta}'(\theta;\delta,\varphi)f'(\alpha x(\theta;\delta,\varphi)+\beta y(e;\eta))h(r)=\delta f(\alpha x(\theta;\delta,\varphi)+\beta y(e;\eta))h'(r)$

$$\alpha x_{\theta}'(\theta;\delta,\varphi)\frac{f'(\alpha x(\theta;\delta,\varphi)+\beta y(e;\eta))}{f(\alpha x(\theta;\delta,\varphi)+\beta y(e;\eta))}=\frac{h'(r)}{h(r)}$$

given in equation (6) .

Table 1. The dependent variables are $PRIVF_{(it)}$ and $PUBF_{(it)}$.

	$PRIVF_{(it)}$			$PUBF_{(it)}$		
	Within	GLS	AM	Within	GLS	AM
Constant	–	2.29 (0.19)	-37.93 (-2.14)*	–	-36.71 (-2.84)*	-62.68 (-3.79)*
$FLOWPUB_{(it)}$	-0.011 (-4.47)*	-0.009 (-3.63)*	-0.01 (-4.46)*	–	–	–
$FLOWPR_{(it)}$	–	–	–	-0.01 (-4.69)*	-0.01 (-4.17)*	-0.01 (-4.41)*
$INTER_{(it)}$	-1.45 (-0.37)	-1.38 (-0.46)	-1.30 (-0.37)	-2.32 (-0.56)	1.55 (0.47)	-0.65 (-0.18)
$INDUS_{(it)}$	3.28 (1.54)	4.33 (2.33)*	3.55 (1.78)	-0.06 (-0.03)	0.06 (0.03)	0.10 (0.05)
$PAT_{(it)}$	-0.36 (-0.26)	1.16 (0.96)	-0.16 (-0.13)	2.40 (1.66)	1.87 (1.43)	2.22 (1.65)
$PIMP_{(it)}$	-0.264 (-5.15)*	-0.03 (-1.01)	-0.23 (-4.99)*	0.08 (1.45)	0.09 (2.54)*	0.11 (2.20)*
$AGE_{(it)}$	1.05 (2.86)*	-0.06 (-0.29)	0.74 (2.35)*	1.95 (5.07)*	0.73 (2.95)*	1.30 (4.18)*
$SIZE_{(i)}$	–	-0.17 (-1.64)	-0.008 (-0.03)	–	-0.07 (-0.59)	-0.05 (-0.23)
$PROMO_{(i)}$	–	0.04 (-0.01)	-3.36 (0.25)	–	-3.59 (0.57)	-6.65 (0.62)
$FTIME_{(i)}$	–	0.62 (0.18)	0.66 (0.08)	–	-3.54 (-0.84)	-3.82 (-0.55)
$PHD_{(i)}$	–	0.30 (2.74)*	0.18 (0.59)	–	0.48 (3.58)*	0.48 (1.96)*
$NONRES_{(i)}$	–	0.07 (1.43)	0.004 (0.03)	–	0.23 (3.92)*	0.21 (1.94)*
$GENDER_{(i)}$	–	-0.56 (-0.09)	-1.40 (-0.09)	–	-6.36 (-0.83)	-9.35 (-0.72)
$NPOST_{(i)}$	–	1.98 (5.43)*	3.22 (2.55)*	–	-0.09 (-0.22)	0.11 (0.12)
$FPOST_{(i)}$	–	0.54 (4.73)*	1.14 (3.28)*	–	0.26 (1.87)	0.21 (0.72)
	–	$\chi^2_{(5)} = 50.28$	$\chi^2_{(13)} = 3.86$	–	$\chi^2_{(5)} = 21.58$	$\chi^2_{(13)} = 0.96$

t statistics are in parentheses. The symbol * indicates that coefficients are statistically significant at the 5 per cent level.