NOTES D'ÉTUDES

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Abstract

This paper examines the impact of financial constraints on innovation for established firms. We make use of a direct measure of the existence of financial constraints obtained thanks to a specific survey addressed to French established firms (FIT, Sessi). This is a distinctive feature of this paper as most of previous studies had to rely on proxies (like the cash-flow sensitivity) which may be subject to interpretation problems. The probability to have innovative activities and the probability to face financial constraints are simultaneously estimated by a recursive bivariate probit model. Accounting for the endogeneity of the financial constraint variable, we find that financial constraints significantly reduce the likelihood that firms have innovative activities. The probability to encounter financial constraints is explained by firms' *ex ante* financing structure and economic performances.

Keywords: innovation, financing constraints, recursive bivariate probit
JEL classification: G31, C35, 031

Résumé

Cet article étudie l'effet des contraintes financières sur le comportement innovant des firmes à partir d'une mesure directe de l'existence de contraintes financières. Cet indicateur direct est obtenu grâce à une enquête spécifique sur le financement des entreprises innovantes dans l'industrie française (FIT, Sessi). Ainsi, contrairement à la plupart des études antérieures, nous ne sommes pas confrontés aux problèmes d'interprétation que soulève l'usage de proxies (comme la sensibilité de l'investissement au cash-flow). La probabilité d'entreprendre un projet innovant et celle de rencontrer des contraintes financières sont estimées simultanément par un modèle probit bivarié récursif. En tenant ainsi compte de l'endogénéité de la variable de contraintes financières, nous mettons en évidence que les contraintes financières réduisent significativement la probabilité qu'une entreprise s'engage dans des activités innovantes. La probabilité de faire face à des contraintes financières est expliquée par la structure de financement et les performances *ex ante* de la firme.

Mots clés: innovation, contraintes financières, probit bivarié récursif
JEL classification: G31, C35, 031

Non technical summary

Because of their specific features in terms of risk and informational asymmetries with external investors, innovative firms may find it difficult to obtain external finance. However, the empirical literature is not as conclusive as one might expect concerning the existence of significant financial constraints. Previous studies examine the effect of firm's wealth (measured by cash flow or past profits) on R&D investment. This approach is strongly criticized in the literature because a positive correlation between R&D and cash flow may also reflect that firms anticipate high future profits that lead them to strongly invest.

To overcome this problem associated with cash flow sensitivity, we use a direct indicator of financial constraints. This indicator is given by a French specific survey addressed to manufacturing firms (FIT, Sessi). In the FIT survey, firms were asked if they met obstacles that prevented them to lead or to undertake innovative projects. In particular, three expressions of the existence of financing constraints are listed:

- no financing source,
- slowness in the setting up of the financing,
- too high interest rates of the financing.

This survey is merged with the Banque de France Balance Sheet dataset in order to have more information about the surveyed firms (their size, economic performance and financing structure). We use it to estimate the impact of financial constraints on the propensity to have innovative activities.

While we obtain the expected results for the traditional determinants of innovation (positive effects of firm size and technology push indicators, significant differences across industries), we find a significant positive impact of financial constraints on the probability to have innovative activities which is incoherent with the theoretical literature. This counter intuitive positive correlation is known as a recurrent problem associated with direct indicators of financial constraints and it can be observed in Mohnen and Röller (2005) or in Lööf and Heshmati (2006).

In this paper, a resolution to this existing paradox is produced. We show that it is due to the combination of two biases. First, the endogeneity of financial constraints has to be taken into account. Second, it seems necessarily to identify firms wishing to innovate. When we properly tackle these problems, we find that the probability to have innovative activities is significantly reduced by the existence of financial constraints for French manufacturing firms.

Résumé non technique

De part leurs spécificités en matière de risque et d'asymétries informationnelles avec les bailleurs de fonds, les entreprises innovantes sont particulièrement susceptibles de rencontrer des difficultés d'accès au financement externe. Cependant, la plupart des études empiriques ne permettent pas de conclure sans ambigüité à l'existence de contraintes financières significatives. Ces travaux examinent la sensibilité de

l'investissement en recherche et développement à des variables reflétant la richesse de l'entreprise (tel que le cash flow ou les profits passés). Or cette approche a fait l'objet de nombreux débats et a été critiquée. En effet, une corrélation positive entre l'investissement et la richesse des entreprises n'est pas systématiquement révélatrice de difficultés d'accès aux financements externes, elle peut également s'interpréter comme résultant d'anticipations de profits futurs importants les conduisant à investir fortement.

Pour surmonter cette difficulté liée à l'usage de proxies, nous utilisons dans cet article un indicateur direct de la présence de contraintes financières. Il est obtenu par le biais d'une enquête réalisée auprès des entreprises industrielles françaises (FIT, Sessi). Dans cette enquête, les entreprises sont interrogées sur les obstacles qui ont pu les conduire à renoncer à leurs projets innovants, à les arrêter ou à les retarder. Parmi les obstacles mentionnés, trois d'entre eux sont l'expression de l'existence de contraintes financières:

- l'absence de source de financement
- une lenteur excessive dans la mise en place des financements
- des taux d'intérêts trop élevés.

Cette enquête est appariée avec les données de la Centrale de Bilans de la Banque de France afin d'avoir des informations supplémentaires sur les entreprises enquêtées (leur taille, leurs performances économiques et leur structure de financement). Nous l'utilisons alors pour estimer l'effet de la présence de contraintes financières sur la propension des firmes à s'engager dans des activités innovantes.

Les déterminants traditionnels de l'innovation donnent le résultat attendu (des effets positifs de la taille de la firme et de l'intensité de la poussée technologique, des différences significatives selon les secteurs d'activité), mais nous obtenons dans un premier temps un effet positif et significatif de la présence de contraintes financières sur la probabilité d'innover qui est incohérent avec la littérature théorique. Ce résultat obtenu à partir d'indicateurs direct de contraintes financières est connu et peut être observé dans Mohnen et Röller (2005) ou encore dans Lööf et Heshmati (2006).

Nous apportons une solution à ce paradoxe en montrant qu'il résulte de la combinaison de deux biais. D'une part, il faut tenir compte de l'endogénéité et de la simultanéité des contraintes financières avec la décision d'innover. D'autre part, il est nécessaire d'identifier les entreprises qui ont souhaité innover. En tenant compte de ces deux problèmes, nous mettons en évidence que l'existence de contraintes financières diminue significativement la probabilité de s'engager dans des activités innovantes.

1 INTRODUCTION

Due to informational asymmetries with external investors, firms may find it difficult and costly to raise external funds to finance their investments (Myers and Majluf 1984, Jensen and Meckling 1976). These financial difficulties may be more severe for innovative projects because their specific features increase the risk and reinforce the informational problems with external investors (Hall 2002).

However, the effect of financial constraints on innovation in the empirical literature is not as conclusive as one might expect. This impact is most often assessed by examining the effect of firms' wealth (measured by cash flow) on R&D investment. Some studies find a significant cash-flow effect (e.g. see Himmelberg and Petersen 1994, Mulkay *et al.* 2001), but this conclusion does not always hold (e.g. see Harhoff 1998 or Bond *et al.* 1999 for German firms). Moreover, it has been stressed that investment cash-flow sensitivity may not be always interpreted as revealing the existence of financial constraints because a positive effect of firm wealth on investment may also reflect that current cash-flow can be a predictor of future profits leading firms to invest more (e.g. see Kaplan and Zingales 1997, 2000 or Gomes 2001).

In order to overcome this problem of interpretation associated with the sensitivity of investment to cash flow, we propose to use a direct indicator based on firms' own assessments. This qualitative indicator of financial constraints is obtained thanks to a French specific survey devoted to the financing of firms' innovation which was conducted by the French Ministry of industry. More precisely, we examine the effect of financial constraints on firm propensity to have innovative activities by using the same type of specification as Crépon *et al.* (1998) where we add our direct measure of the existence of financial constraints to the traditional determinants of innovation (firm's size and market power, the technology push, etc...). While we get expected results for the traditional determinants of innovation, our first estimate of the effect of financial constraints on the propensity to innovate is inconsistent with the theoretical literature: we obtain a positive and significant impact of financial constraints on the likelihood to have innovative activities. This counter intuitive positive correlation is known as a recurrent problem associated with the study of obstacles to innovation as indicated by the Community Innovation Surveys[1] (Mohnen and Röller 2005 ; Lööf and Heshmati 2006). This can probably explain why previous papers about obstacles to innovation do not estimate their impact on the propensity to innovate (Canepa and Stoneman 2003 ; Galia and Legros 2004 for instance).

In this paper, we show that this positive coefficient results from the combination of two sources of bias. First, the endogeneity of the variable measuring the financial constraints has to be tackled. That is why we estimate simultaneously the probability that a firm has innovative activities and the probability that it faces financial

[1] The Community Innovation Surveys (CIS) are conducted in each country by the national statistical entities in order to collect information about the innovative activities of firms. In each country, they are based on the same questionnaire that may be completed by additional questions. The survey used here (Financement de l'Innovation Technologique, FIT) is different because it is fully focused on the financing of innovation. However, its methodological framework is the same as the well-known CIS' one, in particular concerning the definition of innovation and the design of the questionnaire.

constraints with a recursive bivariate probit model. Second, a selection bias seems to exist: it appears necessary to define precisely the sample of firms that wished to innovate in order to examine the impact of obstacles to innovation; otherwise all firms that did not intend to innovate and thus did not meet any financial constraint in this respect induce a positive correlation between these two variables. When we properly take into account these two problems, we find that the probability to have innovative activities is significantly reduced by the existence of financial constraints for French manufacturing firms. Moreover, the paper shows that the likelihood to face financing constraints is linked to the *ex ante* firms' financing structure and economic performances.

The direct indicator of the existence of financial constraints is presented in section 2 and our econometric results obtained thanks to this direct indicator are given in section 3. Finally, section 4 concludes.

2 DEFINING THE EXISTENCE OF FINANCIAL CONSTRAINTS

As mentioned above, previous papers that estimate the impact of financial constraints on innovation (*e.g.* Himmelberg and Petersen 1994, Mulkay *et al.* 2001, Harhoff 1998 or Bond *et al.* 1999) compare the sensitivity of R&D investment to cash flow for subgroups of firms defined according to the likely severity of financial constraints they faced following the methodology initiated by Fazzari *et al.* (1989). To discriminate between likely financially constrained and unconstrained firms, *a priori* criteria (firm size, dividend policy, etc...) or indirect indicators of the firm's financial reliability such as credit-rating index (Czarnitzki 2006) are used. Here, we take another route because we use a direct measure of financial constraints given by the firms themselves.[2] Indeed, in the FIT survey[3] (like in the Community Innovation Surveys), firms were asked if they met obstacles that prevented them to lead or to undertake innovative projects. In particular, three expressions of the existence of financing constraints are listed:

- no financing source,
- slowness in the setting up of the financing,
- too high interest rates of the financing.

We consider that a firm faced financial constraints for its innovative projects if it answered that it had projects which were delayed, abandoned or non started because of at least one of the three obstacles listed above (it is worth noticing that a firm may tick more than one answer). As the goal of this paper is to test whether financing constraints are significant obstacles hampering innovation, we are interested

[2] This qualitative information is then similar to the one used by Angelini and Generale (2005) to examine the effect of financial constraints on firm size. Guiso (1998) and Piga and Atzeni (2005) focus on the determinants of credit rationing and they also adopt a direct indicator of financing constraints taken from a survey. They consider that firms are financially constrained when they applied to bank credit but failed to obtain it.

[3] Our dataset is presented in the appendix.

in identifying firms with innovative activities (and not only those that have completed their innovative projects) and firms without any innovative activities. Then, we adopt a less restrictive definition of "innovative firms" than that of the Oslo manual and we qualified as "innovative" a firm that has introduced or develop a product or process innovation or that has been in process of doing so during the surveyed period.[4]

In our sample, for the quasi-totality of financially constrained firms, the financial constraint simply lies in the absence of external financing sources (see table 1). On top of that, 45% of the firms facing financial constraints declared having suffered from the slowness in the setting up of the financing and about 22% claim they have faced too high interest rates.[5] The existence of financing constraints mainly induced the projects to be non started (for 55.43% of constrained firms) or delayed (44.86% of constrained firms).

Table 1. Details of the financial obstacles

	% of financially constrained firms with :
Type of financial constraints	
No financing source	88.00
Slowness in the setting up of the financing	44.86
interest rate too high	21.71
Details by number of financial constraints faced	
Only one type of financial constraint	***64.00***
No financing source	52.29
Slowness in the setting up of the financing	10.57
interest rate too high	1.14
Two types of financial constraints	***16.85***
No financing source +Slowness in the setting up of the financing	15.43
No financing source +interest rate too high	1.14
Slowness in the setting up of the financing + interest rate too high	0.28
Three types of financial constraints	***19.15***
Consequences of financial constraints	
project(s) delayed	44.86
project(s) abandonned	15.14
project(s) non started	55.43

Note:The modes of financing constraints are not exclusive. Furthermore, a firm may have several innovative projects, the consequences of financial constraints are not exclusive among them, too.

It may be argued that indicators about factors hampering innovation that are

[4] See the details of the identification of innovative/ non innovative firms in the appendix.

[5] Firms were allowed to provide multiple answers.

based on firms' assessments have a drawback: it is possible that firms which had innovative activities are more willing to give details about the difficulties they have encountered when running these projects than firms which were not able to start any innovative project. However, this direct information allows to avoid the interpretation problems of indirect indicators, especially cash-flow. Moreover it provides a specific information about the financial problems encountered by firms for innovative projects whereas accounting variables or credit rating index reflect the global financial situation of the firm.

3 PROPENSITY TO INNOVATE AND FINANCIAL CONSTRAINTS

3.1 The determinants of innovation in the literature

Some major factors are highlighted in the literature to explain firms' innovative behavior (Cohen and Levin 1989): firm's size (Cohen and Klepper 1996) and market power (Schumpeter 1942, Arrow 1962, Aghion *et al.* 2005) as well as the environment.

Firm size is frequently considered to be a proxy of financial constraints. As investments in innovation induce sunk costs, large firms are less reluctant to engage in innovative activities because they can amortize these costs by selling more units of output. In addition, it may be easier to finance innovative investments in large firms which are well-known and may enjoy better relations with external investors or lenders. Among many others, Crépon *et al.* (1998) find a positive significant effect of firm size on the likelihood to undertake R&D.

The impact of market structure on innovation has been stressed for a long time. Schumpeter (1942) argues that a firm is incited to innovate if it enjoys a monopoly position. But Arrow (1962) shows that under perfect ex-post appropriation, the profit margins are larger in an *ex-ante* competitive industry than under a monopoly situation. In this respect, the empirical studies are not in contradiction to the Schumpeterian theory. Blundell *et al.* (1999) find a positive relationship between firms' *ex ante* market share and innovation.[6] Concerning the role of the environment, Rosenberg (1974) argues that technological opportunities contribute to the decision to undertake innovative projects. The technological opportunities may result from the past history of knowledge accumulation and from the technological progress in the firm's environment. They depend on various factors such as the diffusion process of knowledge, the state of art, relationship between firms or cooperation between firms and universities. So, the existence of technological opportunities may induce variations in firms' ability to innovate within an industry. The demand pull is another external factor which may lead innovation (Schmookler 1966). This approach identifies consumer's needs as driving new products or processes. Empirical evidences of the role of the technologic push and of the demand pull are obtained by using

[6] More recently, Aghion *et al.* (2005) propose a model with an inverted U-shape relationship between innovation and competition. In this model, competition may increase innovation profit margin but strong competition may also reduce incentives to innovate for laggards.

qualitative indicators based on firm's own assessment (Barlet *et al.* 1998, Crépon *et al.* 1998).

3.2 Preliminary results

First, we follow Crépon *et al* (1998) and define a univariate probit model where the decision to have innovative activities depends on "traditional" determinants of the decision to innovate emphasized by the literature (noted x_{1i}) and on the qualitative indicator of the existence of financial constraints y_{2i}.

In other words, we specify the latent variable y_{1i}^* underlying this probit model as:

$$y_{1i}^* = x_{1i}a_1 + y_{2i}a_2 + u_i, \tag{1}$$

where the latent variable y_{1i}^* can be interpreted as reflecting the expected return of firm's innovative projects. As presented above, we focus in this paper on the decision to engage in innovative activities (and not on the likelihood to achieve the innovative projects) and we call it "propensity to innovate". We define the binary variable y_{1i} such as:

$$\begin{cases} y_{1i} = 1 \text{ if the firm has innovative activities} \\ y_{1i} = 0 \text{ otherwise} \end{cases}$$

The qualitative variable y_{2i} accounts for the existence of financial constraints (*i.e.*, no financing source, too high interest rates or slowness in the setting up of the financing) encountered by firm i:

$$\begin{cases} y_{2i} = 1 \text{ if the firm faces financial constraints} \\ y_{2i} = 0 \text{ otherwise} \end{cases}$$

The other explanatory variables x_1 qualified as "traditional" determinants of innovation are firm size, firm market share, indicators of the intensity of the technology push[7] and industry dummies.[8]

As a first point, we can notice that our results are very similar to those obtained by Crépon *et al.* (1998) concerning the traditional determinants of innovation (Table 2, column 1). We find that the probability to have innovative activities increases with firm size and with the technology push variables. Moreover, there are significant differences across sectors.[9]

[7] The importance of technological opportunities is given by a qualitative measure issued from the FIT survey. The same indicator was used in previous works such as Crépon *et al.* (1998) or Barlet *et al.* (1998). In the survey, the firms are asked : *"Do You consider that Your market is technologically : not innovative? weakly innovative? moderately innovative? or strongly innovative?"*. We take the first level "*not innovative*" as reference and include in the regression three dummies TP2, TP3 and TP4 for the other levels.

[8] See the definitions of the variables in the appendix (table 7). Moreover, let us remind that in the FIT survey firms were asked about their innovative behavior and possible constraints over the years 1997-1999. To ensure that there is no time inconsistency in the definition of the dependent variable and the regressors, the latter are taken at their value measured *ex ante*, in 1996.

[9] In the FIT survey, there is no information to construct demand pull indicator as it was done by Crépon *et al.* (1998). In order to try to account for demand effect, we have introduced the growth rate of sales of the firm between 1996 and 1997. But we do not obtain a significant estimate. However, the industry dummies control for specific demand effect in each industry sector.

Table 2. Propensity to innovate (probit, full sample)

	Coeff.		Std.Err.	Coeff.		Std.Err.
Traditional determinants						
Constant	-2,511	***	0,211	-2,612	***	0,213
Size	0,322	***	0,032	0,330	***	0,032
Market share	-0,009		0,062	-0,003		0,061
TP4	1,763	***	0,155	1,656	***	0,157
TP3	1,246	***	0,122	1,189	***	0,124
TP2	0,819	***	0,119	0,774	***	0,121
Financial constraint	-		-	0,546	***	0,086
Industry dummies						
DB : Textiles and textile products	-0,506	***	0,150	-0,473	***	0,151
DC : Leather and leather products	-0,457	**	0,232	-0,419	*	0,232
DD : Wood and wood products	-0,356	*	0,211	-0,310		0,213
DE : Pulp, paper and paper products, publishing	-0,538	***	0,135	-0,497	***	0,137
DG : Chemicals industry	-0,265	*	0,159	-0,201		0,160
DH : Rubber and plastics	-0,230		0,149	-0,199		0,151
DI : Other non-metalic mineral products	-0,258		0,168	-0,267		0,170
DJ : Basic metals and fabricated metal products	-0,303	***	0,115	-0,288	**	0,116
DK : Machinery and equipment	0,239	*	0,133	0,267	**	0,134
DM : Transport equipment	-0,049		0,164	-0,042		0,167
DN : Other manufacturing industries	-0,206		0,160	-0,187		0,161
Log likelihood fonctions			-1081			-1060
R^2 Mac Fadden			0,180			0,196
Number of firms			1940			1940

*/**/*** indicates significance at the 10%/5%/1% levels

When we introduce our indicator of the existence of financial constraints in this equation (column 2), we obtain a surprising and incoherent positive effect of the existence of financial constraints on the propensity to innovate. As mentioned in introduction, this is known as a recurrent problem associated with the study of obstacles to innovation that are collected in the framework of the Community Innovation Surveys, too. Such a result can be observed in Mohnen and Röller (2005) or in Lööf and Heshmati (2006). This direct information about obstacles to innovation is not widely exploited, maybe due to this "unexpected" positive correlation between innovation and the obstacles to innovation. For instance, the financial obstacles to innovation are studied by Canepa and Stoneman (2003) with the Community Innovation Surveys. This paper provides a lot of interesting descriptive statistics for European countries using a similar indicator taken from the Community Innovation Surveys but does not estimate the impact of financial constraints on firms' propensity to innovate.

We can suspect that this positive correlation between innovation and its obstacles results from some bias that have to be tackled. In particular, a problem of endogeneity of the financial constraint variable is quite likely and may lead to bias the estimated coefficient. Moreover, an inadequate selection of firms asked about obstacles to innovation in this type of survey may be an additional source of bias.

3.3 Endogeneity of the financial constraints

The endogeneity of the financial constraints may be due to two main factors. First, the decision to undertake innovative projects and the probability to face financing constraints are likely to be both affected by common elements of unobservable heterogeneity. The uncertainty associated with the output of the innovative project or the eventual confidentiality of the project for strategic reasons are unobservable firm specific risk factors which may create or worsen financial constraints. In addition, we have no information concerning the duration needed to bring the innovative projects onto the market whereas this factor may have an effect both on the decision to innovate and on the likelihood to face financing problems. Second, the decision to engage in innovative activities and the way to finance this new investment are probably simultaneously determined.

Thus, we consider the decision to innovate and the likelihood to face financial constraints as simultaneous questions. Each variable is likely to affect the other one: the existence of financing constraints by reducing the likelihood to have innovative activities and the innovative behavior by inducing financing difficulties. A latent variable model accounting for these relations is:

$$\left\{ \begin{array}{l} y_{1i}^* = x_{1i}\beta_1 + \gamma_1 y_{2i} + \varepsilon_{1i} \\ y_{2i}^* = x_{2i}\beta_2 + \gamma_2 y_{1i} + \varepsilon_{2i} \end{array} \right. \tag{2}$$

where y_{1i}^* and y_{2i}^* represent respectively the expected return of the innovative projects and the (unobservable) severity of financial constraints. As defined above, x_{1i} accounts for the traditional determinants of innovation. The explanatory factors of the financial constraint, x_{2i}, are essentially the risk associated with the investment and the information asymmetry with external investors. These factors can be measured by: firm size, its collateral, its *ex ante* financing structure and its past economic performances.

We know whether or not the firm has innovative activities and whether or not it suffers from financial constraints. We observe:

$$\left\{ \begin{array}{l} y_{1i} = 1 \text{ if } y_{1i}^* \geq 0 \\ y_{1i} = 0 \text{ if } y_{1i}^* < 0 \end{array} \right. \quad \text{and} \quad \left\{ \begin{array}{l} y_{2i} = 1 \text{ if } y_{2i}^* \geq 0 \\ y_{2i} = 0 \text{ if } y_{2i}^* < 0 \end{array} \right.$$

Unfortunately, such a model is inconsistent (Maddala 1983, Gouriéroux *et al.* 1980, Lewbel 2005, Hajivassiliou 2005) and some restrictions are needed on the coefficients to be logically consistent. This model is logically consistent if and only if γ_1 or γ_2 is set equal to zero. Following Ploetscher and Rottmann (2002), we consider the model obtained by setting γ_2 equal to zero:

$$\left\{ \begin{array}{l} y_{1i}^* = x_{1i}\beta_1 + \gamma_1 y_{2i} + \varepsilon_{1i} \\ y_{2i}^* = x_{2i}\beta_2 + \varepsilon_{2i} \end{array} \right. \tag{3}$$

Moreover, for identification purposes, it is necessary to adopt the standard normalization of the variance of the errors (for instance see Train 2003). We assume that

the error terms are independently and identically distributed as bivariate normal:

$$\begin{pmatrix} \varepsilon_{1i} \\ \varepsilon_{2i} \end{pmatrix} \rightsquigarrow \Phi_2 \left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \right)$$

No additional restrictions on the parameters are needed to achieve the identification of this bivariate probit model with endogenous dummy regressor (Wilde 2000, Monfardini and Radice 2006).[10]From the econometric point of view, the endogenous nature of y_2 in the first equation of (3) does not modify the likelihood of the standard bivariate probit (Greene 1998, 2003). Then, the probability of each event is just given by the value of the bivariate normal cumulative distribution function, like in a standard bivariate probit model without endogeneity:

$$\begin{aligned}
\Pr(y_1 &= 1, y_2 = 1) = \Phi_2 \left(x_1\beta_1 + \gamma_1, x_2\beta_2, \rho \right) \\
\Pr(y_1 &= 1, y_2 = 0) = \Phi_2 \left(x_1\beta_1, -\left(x_2\beta_2 \right), -\rho \right) \\
\Pr(y_1 &= 0, y_2 = 1) = \Phi_2 \left(-\left(x_1\beta_1 + \gamma_1 \right), x_2\beta_2, -\rho \right) \\
\Pr(y_1 &= 0, y_2 = 0) = \Phi_2 \left(-\left(x_1\beta_1 \right), -\left(x_2\beta_2 \right), \rho \right)
\end{aligned}$$

The correlation coefficient ρ between the disturbances accounts for the possible existence of omitted or unobservable factors that affect simultaneously the decision to innovate and the likelihood to face financing constraints. If $\rho = 0$, y_{2i} is not correlated with the error term ε_{1i}. In this case, the two equations could be estimated separately as univariate probit equations. Whereas, if $\rho \neq 0$, a joint estimation is required to obtain consistent estimates. The calculation of the marginal effects in the recursive bivariate probit model is given in Greene (1998, 2003). For a continuous variable entering both equations (for instance, firm size), the total effect on the probability to innovate is the sum of a direct effect (due to $\Pr\left(y_1|y_{2,}x_1\right)$) and an indirect effect (through $\Pr\left(y_2|x_2\right)$). The marginal effect of a qualitative variable is measured by the difference between the conditional probabilities. For example, the marginal effect of the existence of financing constraints on the likelihood to have innovative activities is given by:

$$\Pr(y_1 = 1|y_2 = 1, x_1, x_2) - \Pr(y_1 = 1|y_2 = 0, x_1, x_2)$$

3.4 Sample selection

The survey used in this paper is focused on the financing of innovation but its design is very similar to the CIS' one. It begins by questioning firms about their innovative

[10]There is some confusion about this question because of Maddala's assertion (1983, p 222). He states that the parameters of the first equation are not identified if there is no exclusion restriction on the exogenous variables (as in the linear case). But Wilde (2000) shows that this is only true in the simple example of Maddala's book where x_{2i} and x_{1i} are both constants. Wilde shows that identification in the simultaneous probit case is achieved as soon as both equations of the model contain a varying exogenous regressor. However, as examined by Monfardini and Radice (2006), without instruments, the identification of the parameters of the first equation strongly relies on the functional form of the distribution of errors and in practice, availability of instruments help to obtain results which are more robust to distributional misspecification.

behavior. Then, the firms with innovative activities during the surveyed period have to answer a set of questions about the financing of their innovative projects while the firms without innovative activities have directly to go to the last part of the questionnaire. In this last part of the questionnaire, *all surveyed firms* are asked about the obstacles to innovation (financial constraints as well as non financial obstacles such as a lack of qualified employees) and about the consequences of those obstacles on their innovative projects.

A significant part of firms in our initial sample (44%) answered simultaneously *(i)* that they did not have any innovative activities, and that *(ii)* they did not encounter any obstacle to innovation. Consequently, it could be assessed that this group of firms did not **wish** to innovate and thus, that those firms were not concerned by obstacles to innovation in general and by financial obstacles in particular. In other words, we wonder about the relevance to ask all surveyed firms (in this specific survey as well as in the CIS'ones) about obstacles to innovation to get reliable information on the factors hampering innovation. It would be better to ask only firms which **wished to innovate** about the potential obstacles they faced. Indeed, asking about obstacles to innovation the firms which did not wish to innovate (and consequently which did not face obstacles to innovation) may lead to the global positive correlation found above between the propensity to innovate and the existence of financial constraints. To check for this possibility, we define :

- the firms not wishing to innovate (*i.e.* firms without innovative activities and without any obstacle to innovation) and we name these firms "Others",

- and the firms wishing to innovate and we name them the "potentially innovative firms". Among the "potentially innovative" firms, some of them have innovative activities (they succeeded in starting, even in completing, their projects) while the other ones were not able to start their innovative projects.[11]

In other words, this differentiation between the firms wishing to innovate and the firms not wishing to innovate leads to segment *non innovative* firms into two categories *i)* potentially innovative firms that did not start innovative projects and *ii)* other firms that did not intend to have innovative activities.

The distribution of the firms in our sample as well as some descriptive statistics computed according to these categories (and according to the occurrence of financial obstacles) are shown in table 3 below.

[11] See the details of these definitions in the appendix.

Table 3. Some descriptive statistics

	Potentially innovative firms				Others
	Firms with innovative activities		*Firms without innovative activities*		
	Constrained	Unconstrained	Constrained	Unconstrained	
Number of firms	198	613	112	159	858
Some ratios (% of value added)					
Immaterial expenditure***	6.193	4.690	4.150	4.008	3.778
Gross operating profit margin ***	13.920	22.632	6.837	18.397	18.637
Financial fees***	5.259	3.254	5.361	3.237	3.408
Self financing capacity***	11.479	16.920	3.183	14.872	14.576
Dividends distribution**	2.404	4.967	2.598	3.072	4.639
Firms' financing structure (% of total ressources)					
Own financing***	73.203	78.808	67.118	74.808	78.273
Market financing	0.153	0.233	0.166	0.353	0.135
Financial debt***	26.787	21.192	32.881	25.551	21.727
- Bank loans***	16.983	13.032	21.951	16.802	14.053
*Long-term bank loans****	8.159	7.070	8.206	8.555	7.223
*Short-term bank loans****	8.823	5.961	13.744	8.245	6.830
- Financing by group companies	6.992	5.637	6.283	6.254	5.546
- Other extra-group financial debt***	2.668	2.289	4.483	2.143	1.992

Average ratio calculated by using variance analysis for a given size and industry

*/**/*** indicates significant difference for the type of firm at the 10%/5%/1% level.

According to the figures above, the different types of firms are characterized by specific features concerning their performances and financing structure. As expected, innovative firms and particularly the financially constrained ones have a higher immaterial expenditures ratio (immaterial expenditures divided by value added). Another interesting feature is the existence of an apparent hierarchy across categories concerning the ability of firms to earn profits. This is highlighted by various income ratios such as the gross operating profit margin, the share of financial fees in value added or the self-financing capacity ratio. Not surprisingly, firms without financial constraints seem to perform better than the financially constrained ones. In addition, in each case, innovative firms have better ratios than non innovative ones whether or not they face financial constraints. Moreover, it can be noticed that the firms not wishing to innovate ("Others", in the last column) seem to enjoy good indicators that are very closed to those of the innovative and non financially constrained firms.

The financing structure confirms the existence of significant differences across the type of firms. The average share of own financing in the total sources of funds (measured as the sum of own financing, market financing and financial debt) varies between 78.80% for unconstrained innovative firms and 67.12% for non innovative firms facing financial constraints. In the same way, financial debt represents only 21.19% of the total source of funds for innovative firms without financial constraints while it amounts to 32.88% for non innovative firms having financing constraints. By analyzing the components of the financial debt, we can see that these differences come from bank loans and especially short term bank loans which are an indicator

of firm's financial fragility.

As it was showed by Planès *et al.* (2002), firms engaged in innovative activities enjoy a better financial situation than non innovative ones. This is consistent with the idea that there is a kind of selectivity at play concerning the decision to innovate for the firms which perform better (Bond *et al.* 1999). In addition, these figures reveal that the firms that can be viewed to be not interested in innovative activities (*i.e.* firms without innovative activities and without any obstacle to innovation) have a good profile in terms of performances and financial reliability.

3.5 Dealing with endogeneity and selection

The estimates obtained with the recursive bivariate probit on the full sample as well as on the sample of potentially innovative firms are presented in table 4 below.[12]

The first striking result is the fact that we do get now a strong and significant negative impact of financial constraints on firm propensity to be innovative. The estimation of the bivariate probit shows a strong positive correlation between the error terms of both equations in the full sample ($\rho = 0,604$) as well as in the sub-sample of potentially innovative firms ($\rho = 0,572$). Accounting for the endogeneity of the financial constraint, we obtain a significant negative effect of the financial constraints, while all other estimates remain unchanged. Consequently, elements of unobservable heterogeneity affecting both the existence of financial constraints and the probability to innovate play a great role and must be taken into account.

According to the estimated marginal effects (table 5), the impact of financial constraints is quite important: they reduce by more than 20% the likelihood to have innovative activities, everything else being equal.

[12] The univariate probit regression on the subsample of "potentially innovative" firms is given in the appendix (table 6).

Table 4. Bivariate probit model

	Full sample			Potentially innovative firms		
	Coeff.		Std.Err.	Coeff.		Std.Err.
Index equation for having innovative activities						
Traditional determinants						
Constant	-2,121	***	0,278	-0,496		0,365
Size	0,305	***	0,034	0,224	***	0,057
Market share	-0,001		0,055	0,628	**	0,243
TP4	1,504	***	0,170	1,195	***	0,229
TP3	1,068	***	0,134	0,770	***	0,182
TP2	0,690	***	0,121	0,371	**	0,172
Financial constraints	-0,550	**	0,268	-1,380	***	0,247
Industry dummies						
DB : Textiles and textile products	-0,590	***	0,148	-0,487	**	0,206
DC : Leather and leather products	-0,551	***	0,215	-0,278		0,414
DD : Wood and wood products	-0,489	**	0,209	-0,401		0,282
DE : Pulp, paper and paper products, publishing	-0,621	***	0,132	-0,336	*	0,186
DG : Chemicals industry	-0,376	**	0,164	-0,689	***	0,215
DH : Rubber and plastics	-0,310	**	0,148	-0,624	***	0,207
DI : Other non-metalic mineral products	-0,322	*	0,168	-0,428	*	0,220
DJ : Basic metals and fabricated metal products	-0,369		0,114	-0,021		0,162
DK : Machinery and equipment	0,149		0,137	0,162		0,194
DM : Transport equipment	-0,083		0,162	0,012		0,226
DN : Other manufacturing industries	-0,312	*	0,166	-0,442	**	0,212
Index equation for facing financing constraints						
Constant	-0,816	***	0,237	0,581	*	0,329
Size	-0,002		0,070	-0,036		0,084
Collateral amount	0,030		0,048	-0,034		0,060
Banking debt ratio	0,010	***	0,002	0,006	*	0,003
Own financing ratio	-0,003	***	0,001	-0,012	***	0,003
Gross operating profit margin ratio	-0,008	***	0,002	-0,009	***	0,002
Industry dummies						
DB : Textiles and textile products	-0,549	***	0,162	-0,344	*	0,207
DC : Leather and leather products	-0,452	*	0,242	-0,075		0,320
DD : Wood and wood products	-0,888	***	0,257	-0,771	***	0,303
DE : Pulp, paper and paper products, publishing	-0,629	***	0,155	-0,405	**	0,184
DG : Chemicals industry	-0,685	***	0,189	-0,707	***	0,212
DH : Rubber and plastics	-0,443	***	0,164	-0,489	***	0,190
DI : Other non-metalic mineral products	-0,234		0,176	-0,152		0,210
DJ : Basic metals and fabricated metal products	-0,405	***	0,122	-0,138		0,147
DK : Machinery and equipment	-0,303	**	0,142	-0,375	**	0,162
DM : Transport equipment	-0,204		0,183	-0,159		0,205
DN : Other manufacturing industries	-0,405	**	0,172	-0,307		0,204
Disturbance Correlation : rho	0,604	***	0,147	0,572	***	0,161
Log likelihood fonctions			-1858,1			-1088
Number of firms			1940			1082

*/**/*** indicates significance at the 10%/5%/1% levels

Table 5. Estimated marginal effects at the sample means on the probability to have innovative activities

	Full sample			Potentially innovative firms		
	Direct	Indirect	Std.Err.	Direct	Indirect	Std.Err.
Market share	-0,0049		0,0185	0,0653		0,0430
Financial constraints	-0,2158		0,1062	-0,2655		0,0289
Size	0,1029	0,0004	0,0283	0,0232	0,0018	0,0156
Banking debt ratio		-0,0017	0,0003		-0,0003	0,0002
Own financing ratio		0,0005	0,0001		0,0006	0,0002
Gross operating profit margin		0,0014	0,0003		0,0005	0,0002

As expected, the likelihood for a firm to have innovative activities increases with its size and with the importance of its technological opportunities. In addition, the sector dummies show strong disparities in the probability of undertaking innovative projects across industries.

We have also run the regression with a proxy of firm wealth as it is done by previous studies, and we get a significant positive effect on the propensity to innovate.[13] However, as the strong debate found in the literature shows, it is difficult to interpret this positive effect as revealing the impact of financing constraints on innovation. Here, our result with the direct information about obstacles to innovation leads to conclude without ambiguity that the firms face financial constraints that significantly reduce their probability to be innovative.

Concerning the likelihood to face financial constraints, the estimation also provides quite satisfactory results. A high gross operating profit margin ratio as well as large own funds reduce the probability to encounter financial constraints while having a high banking debt increases the likelihood to be financially constrained. Indeed, the share of own funds and good past performances are positive indications concerning the financing reliability of the firm, whereas a too high financial debt constitutes a weakness of its balance sheet structure. The significant industry dummies can be interpreted as reflecting differences in the risk across the manufacturing sectors.

Here, we do not obtain a significant effect of firm size nor of the collateral (measured by tangible assets) on the probability to face financial constraints. To check for a possible redundancy problem due to the introduction of both variables, we run the estimations without the collateral but do not obtain a significant effect of firm size.[14] Indeed, it is difficult to get a reliable measure of the collateral, in particular for innovative firms. The tangible assets may be a poor proxy of the collateral because they may be firm specific due to the firm's innovative character. To account for the risk faced by external suppliers of funds (in particular banks) as well as for the firms' ability to repay their creditors, it would be very interesting to examine whether the probability to be financially constrained is lower for firms that are part

[13] Such a test have been made with cash flow or profit margins and the results can be obtained from the author.

[14] We have also checked for non linear effects by introducing the square of firm size but it does not change the results.

of a corporate group. Indeed, the head of the group may provide guarantees for its subsidiary companies and funds given by the head of the group may weaken the need for external finance. Unfortunately, we do not have an enough precise information about the group membership to conduct such an analysis.

From the econometric point of view, it is worth noticing that the differences between the estimates of the impact of financial constraints in the univariate probit model and in the bivariate one are quite similar in the full sample and in sample restricted to potentially innovative firms. As a result, the bias induced by the endogeneity of the financial constraints seems to be the same in both samples. Indeed, the smaller coefficient (in absolute value) obtained with the full sample as well as the paradoxically positive coefficient that we have with the univariate probit model as a preliminary result are due to the combination of the bias due to the endogeneity problem with another bias due to the structure of the full sample (*i.e.* the full sample contains a large proportion of firms that can be considered to be not interested in innovation, and thus without financial obstacles to innovation). Here, the endogeneity problem is tackled by estimating the bivariate recursive probit and the sub-sample of "potentially innovative firms" has been defined to avoid the spurious positive correlation due to the firms not wishing to innovate. However, to improve the reliability of the firms' responses to the questions about the obstacles to innovation in surveys focused on innovation (this specific survey as well as the Community Innovation Surveys), it would be useful to ask only the firms that wished to innovate about the obstacles they face.

4 CONCLUSION

In this paper, we estimate the impact of financial constraints on the decision to engage in innovative activities. We use a qualitative indicator of the existence of financial constraints based on firm's own assessment avoiding the traditional problems linked to the interpretation of cash-flow effects.

We show that the likelihood that a firm will have innovative activities is significantly reduced by the existence of financing constraints. This reduction is estimated to amount to more than 20% everything else being equal.

By considering the existence of financing constraints as endogenous to the innovation decision, we stress the role played by firm *ex ante* financing structure and past economic performances on the existence of financial constraints.

Furthermore, this paper produces a resolution to an existing paradox: not taking account of the endogeneity of financing constraints, leads one to incorrectly conclude that presence of financing constraints and innovation are positively correlated.

Although the goal of this paper was to study the financial obstacles to innovation, it may be interesting to look at the other obstacles to innovation (such as a lack of qualified employees). To tackle a likely similar problem of endogeneity, the likelihood to face these obstacles has to be estimated simultaneously with the likelihood to innovate. Such a model requires explanatory variables of these non financial obstacles that we did not have in our data set. Finally, to go deeper into this question of the

financing of innovation in established firms, it would be necessary to have more information about the projects themselves (in particular concerning the duration of the project from the R&D stage to the introduction of the output onto the market). The role of the financing within the company for firms belonging to a group structure is another relevant question for future research.

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5 APPENDIX

We use data from two sources: a survey about the financing conditions of innovative projects for established manufacturing firms and the Banque de France Balance Sheet Data.

The FIT survey

The survey we used, named "Financement de l'Innovation Technologique" (FIT) was conducted in 2000 by the French Ministry of Industry. Its aim was to obtain statistical information about the financing conditions of innovative projects of manufacturing firms in France. This survey allows to identify the firms which undertook innovative projects between 1997 and 1999 and it gives qualitative information about the financial constraints that firms may have experienced when planning and conducting those projects. A sample of 5500 industrial companies was surveyed. It is composed by manufacturing firms with 20 employees and more (excluding agricultural-food and building sectors). It is important to notice that start-ups and new established firms are not in the field of this survey. Globally, the rate of response amounts to 70% (Sessi 2002) so that about 3700 firms are present in the available FIT sample.

As the Community Innovation Surveys (CIS), the FIT survey is based upon the technological innovation concept exposed in the Oslo manual (OECD 1997).

- We qualified as **innovative** a firm that has introduced or developed a product or process innovation or that has been in process of doing so during the surveyed period.

This identification of innovative firms is made thanks to their answers to the three following questions:

1) In 1997, 1998 or 1999, did Your enterprise introduce onto the market any new or significantly improved products for Your enterprise?

2) In 1997, 1998 or 1999, did Your enterprise introduce onto the market any new or significantly improved process for Your enterprise?

3) In 1997, 1998 or 1999, did Your enterprise have projects of new or significantly improved products or processes:

- Which are not yet completed or not yet introduced to the market?

- Which were failures?

Then, we consider that a firm had innovative activities ($y_{1i} = 1$) when it answered positively to at least one of these three questions.

- The qualitative information about the obstacles to innovation is given in the last part of the questionnaire. **All surveyed firms** have to answer the following question:

In 1997, 1998 or 1999, what are the obstacles that have prevented your firm to conduct or to start innovative projects (multiple answers possible)?

- Excessive perceived economic risk
- Lack of qualified personnel
- Innovation costs too high
- Lack of sources of finance
- Slowness in the setting up of the financing
- Too high interest rates of the financing
- Excessive get out clause in the shareholder agreement
- Lack of knowledge about ad hoc financial networks
- No obstacle

For each hampering factor listed the firm has to tick what was its effect on their innovative projects: seriously delayed, abandoned or prevented to be started.

We consider that a firm faced **financial constraints** when it answered that it has seriously delayed, abandoned or non started projects because of:

- Too high interest rates
- Lack of sources of finance
- Slowness in the setting up of the financing

The **potentially innovative firms** are *(i)* firms that positively answered to the first three questions (*i.e.* firms that introduced or developed a product or process innovation and that were in process of doing so during the surveyed period) **or (ii)** the firms that faced obstacles to innovation. In other words, this group of firms is composed by innovative firms plus firms with non started projects due to factors hampering innovation.

Consequently, the **"other" firms** (firms not wishing to innovate) are the non innovative firms that ticked they faced no obstacle to innovation.

The Banque de France Balance Sheet Dataset

In order to have more information about the surveyed firms (their size, economic performance and financing structure) we use the Banque de France Balance Sheet Data set.[15] This is a database containing essentially very detailed accounting data of French companies, obtained from their fiscal forms plus some complementary questionnaires. The database includes all businesses with more than 500 employees and a fraction of smaller firms so that the member firms amount to around 34,000 companies. It achieves an overall coverage rate of 57% in industry (in terms of number of employees). This rich database is used by the Banque de France to update knowledge of the structure and performance of the French productive system. In addition, it makes it possible for example, to pinpoint sources of financing, to isolate group financing or to identify expenditures in intangible goods and services.

[15] The "Centrale de bilans" dataset.

Our sample results from the matching of these two sources. We were able to recover about 60% of the FIT sample companies. After some necessary cleaning, our sample contains 1940 firms.[16]

Table 6. Propensity to innovate (probit, sub-sample of potentially innovative firms)

	Coeff.	Std.Err.	Coeff.	Std.Err.
Traditionnal determinants				
Constant	-1,222 ***	0,342	-1,074 ***	0,347
Size	0,274 ***	0,056	0,268 ***	0,057
Market share	0,758 **	0,299	0,715 **	0,298
TP4	1,198 ***	0,239	1,331 ***	0,243
TP3	0,813 ***	0,196	0,879 ***	0,198
TP2	0,390 **	0,191	0,439 **	0,192
Financial constraint	_	_	-0,524 ***	0,098
Industry dummies				
DB : Textiles and textile products	-0,401 *	0,211	-0,424 **	0,214
DC : Leather and leather products	-0,184	0,347	-0,172	0,357
DD : Wood and wood products	-0,202	0,301	-0,255	0,303
DE : Pulp, paper and paper products, publishing	-0,228	0,199	-0,254	0,201
DG : Chemicals industry	-0,451 *	0,231	-0,536 **	0,233
DH : Rubber and plastics	-0,497 ***	0,211	-0,540 **	0,213
DI : Other non-metalic mineral products	-0,458 **	0,228	-0,430 *	0,231
DJ : Basic metals and fabricated metal products	-0,020	0,167	0,013	0,169
DK : Machinery and equipment	0,316	0,192	0,300	0,195
DM : Transport equipment	0,035	0,235	0,038	0,236
DN : Other manufacturing industries	-0,326	0,217	-0,346	0,221
Log likelihood fonctions	-516,208		-501,894	
R^2 Mac Fadden	0,152		0,175	
Number of firms	1082		1082	

*/**/*** indicates significance at the 10%/5%/1% levels

[16] The manufacture of coke, refined petroleum products and nuclear fuel has been deleted because only two firms were present in the merged dataset. In addition, the firms with negative value added or with abnormally high investment rates have been excluded. This concerns only two firms.

Table 7. Definition of variables

Dependent variable : innovation	=1 if the firm has innovative activities, =0 otherwise
Size	log(number of employees)
Market share	firm sales/sales of the sector x100
TP1	=1 if the firm's market is technologically not innovative (mode of reference)
TP2	=1 if the firm's market is weakly innovative,
TP3	=1 if the firm's market is moderately innovative
TP4	=1 if the firm's market is strongly innovative
Financial constraints	=1 if the firm faces financial constraints, =0 otherwise
Industry dummies	
Dependent variable: financial constraints	=1 if the firm faces financial constraints, =0 otherwise
Size	log(number of employees)
Collateral	log(tangible assets)
Banking debt ratio	Banking debt/(Own financing+market financing+financial debt) x100
Own financing ratio	Own financing/(Own financing+market financing+financial debt) x100
Gross operating profit margin	EBDIT/value added x100
Industry dummies	

Sources : Centrale de Bilans (Banque de France), FIT (Sessi) and EAE (INSEE)

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