The Impact of Financial Constraints on Innovation: Evidence from French Manufacturing Firms

Frédérique Savignac*
Banque de France
ERUDITE, Université Paris 12 Val-de-Marne

August 2005

Abstract

This paper examines the impact of financial constraints on innovation for established firms. We make use of data from a specific French survey about the financing of innovation by firms. In particular, an indicator based on firm's own assessment is used to define the existence of financial constraints. Because the decision to innovate and the existence of financial constraints are both affected by unobservable heterogeneity, we show the importance of taking this heterogeneity into account by estimating a recursive bivariate probit model. We then find that financial constraints significantly reduce the probability that a firm undertakes innovative projects. Moreover, our results lead to the traditional conclusions: firm's size, its market share, technology push and industry sector have significant effect on the likelihood of being innovative.

Keywords: innovation, financial constraints, recursive bivariate probit

JEL classification: G32, C35, 031

*I thank P.Sevestre for his helpful suggestions and advice. I am grateful to P.Mohnen, F.Mouriaux, M.Bardos and to participants of ERUDITE seminar for their comments. I also thank the Sessi (French Ministry for Industry) for providing the data of the survey "Le financement de l'innovation technologique". This paper represents the views of the author and should not be interpreted as reflecting those of Banque de France. I remain responsible for all errors. Banque de France, Observatoire des Entreprises, UA 44-1356, 31 rue Croix des Petits Champs, F-75049 Paris, and ERUDITE, Université Paris 12 Val-de-Marne. Tel : 33-1-42-92-41-80 E-Mail: frederique.savignac@banque-france.fr

1 Introduction

As it is largely stressed in the theoretical literature, the realization of innovative projects is very likely to undergo financial constraints. Indeed, funding such projects with external finance is difficult and costly to firms due to the strong information asymmetry associated with such innovative investments (Hall(2002), Schroth and Szalay (2004)). However, the empirical evidence about the impact of these constraints on innovation is quite sparse and not as conclusive as one might expect. A first strand in this empirical literature rely on R&D investment models where additional variables such as cash-flow are considered to account for financial constraints. Although a number of studies find a significant cash-flow effect on R&D investments by firms (e.g. see Himmelberg and Petersen (1994), Mulkay et al.(2001)), 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 (see Kaplan and Zingales (1997, 2000)). A second strand in the literature aims at modeling firms' propensity to innovate. This literature identifies four predominant factors (Cohen and Levin, 1989). Some of these determinants are firm specific (as firms size and their monopoly power), others relate to environmental factors linked to the market ("demand pull") or to technological opportunities ("technology push"). Quite surprisingly, papers estimating the probability that a firm undertakes innovative activities often ignore the firm's financing conditions (e.g. see Crépon *et al.* (1998, 2000), Mohnen and Therrien (2002), Lööf and Heshmati (2002)). Indeed, there are very few studies that account for the existence of financial constraints and, when they do so, they also use firms' cash-flows or past profitability as proxies for financial constraints (see Bond et al. (1999), Harris et al. (2003)).

This article aims at directly estimating the impact of financial constraints on innovation decisions. Our empirical analysis takes partially up the framework of Crépon *et al.* (1998, 2000) which is used in several recent studies (Janz *et al.* (2003), Jans and Peters (2002)). However, we depart from this framework in two respects. First, we focus only on the first step of their model: the decision to engage into innovative activities. Second, we put a particular stress on the role of financial factors on firms decisions, which was not done in their paper. For that purpose, we use a survey about the financing of innovation by French manufacturing firms that allows to avoid the difficulties associated with the cash-flow sensitivity measure (Kaplan and Zingales, 1997). As far as we know, it is the first time that such a direct information based on firm's own assessment is used to characterize the existence of financial constraints. We find that, indeed, the existence of financial constraints significantly reduces the likelihood that a firm will undertake innovative projects. In addition, we obtain similar results as previous works about the traditional determinants of innovation: the likelihood that a firm implements innovative projects differs across industries and it increases with its size, its market share and with the importance of the technology push. Concerning firm's financing problems for innovation, our results shows that the existence of financing constraints is explained by firm's *ex ante* financing structure and economic performance. Moreover, from a more technical point of view, we show

that the existence of financial constraints is endogenous to the decision to engage into an innovative project. As a consequence, a univariate probit model explaining the decision to innovate fails to give an estimate of the impact of financial constraints that is consistent with the theoretical background while considering a recursive bivariate probit model to account for unobservable heterogeneity (that affects both the decision to undertake innovative projects and the existence of financial constraints) leads to much more satisfactory results.

This paper is organized as follows. Section 2 briefly reviews the theoretical and empirical background. Section 3 describes the data sets: the data sources as well as some descriptive statistics on firms balance sheet structure are presented. Section 4 exposes the econometric models and discusses the estimation results. Section 5 concludes.

2 Firms' decisions to innovate: theoretical and empirical background

Due to informational asymmetries with external investors, firms may find it difficult and costly to raise external funds for their investments financing (Myers and Majluf (1984)). Another possible explanation of the difference between the costs of external and internal funds lies in moral hazard problems caused by the separation of ownership and management (Jensen and Meckling, 1976). In the case of innovative investments, financing constraints may be more severe. In fact, innovative investments present special features that increase the risk and reinforce the informational problems with external investors. The uncertainty linked to the final output of an innovative project may be important and this makes innovative investments particularly risky. Moreover, in general, external investors have no specific knowledge to properly evaluate the impact of a new product or production process on a firm development. Given their firm-specific nature, innovative projects may indeed be viewed as inducing high transaction costs of which financial constraints are a counter-part (Williamson, 1988). These projects constitute specific assets which present sunk costs that may have relatively little value beyond their use in the context of a specific firm/transaction. Moreover, innovative investments contain a large part of intangible assets (such as R&D expenses, payment of wages of highly educated engineers...) which cannot be used as collateral value to secure firms' borrowing. Consequently, this weakens firms financial reliability from the external investors' point of view. Those asymmetric information problems and the uncertainty about the project output can even induce credit rationing (Stiglitz and Weiss (1981), Williamson (1987)).

Empirically, the existence of financial constraints for innovative firms is most frequently investigated by examining the sensitivity of R&D investment to financial factors (Himmelberg and Petersen (1994), Harhoff (1998), Mulkay *et al.* (2001)). It is estimated by using the same models as for physical investment (see Mairesse *et al.* (1999)), that is to say, by using the reduced form of accelerator models of investment (Fazzari *et al.* (1988), Bond *et al.* (1997)) or by using the structural framework of Euler equations (Bond and Meghir (1994)). Himmelberg and Petersen

(1994) find a large and significant relationship between R&D and internal finance for US small firms in high-tech industries. Similar results are obtained by Mulkay *et al.* (2001) with French and United States firms. Harhoffs' results about German firms are less conclusive. He finds a weak but significant cash-flow effect on R&D by using an investment accelerator model, while Euler-equation estimates appear to be not informative. However, Kaplan and Zingales (1997, 2000) show that investment cash-flow sensitivity may not be always interpreted as revealing the existence of financial constraints. Cash-flow provides information about future investment opportunities; thus, investment cash-flow sensitivity may equally occur because firms are sensitive to demand signals.

Otherwise, there are very few studies looking at the direct impact of financial constraints on firms' decision to undertake innovative activities. Bond *et al.* (1999) look in particular at the impact of financial constraints on firms' propensity to innovate by examining cash-flows' effect. They do find that cash-flows have a positive and significant effect on the likelihood that British firms perform R&D. For Australian firms, Harris *et al.* (2003) use past profitability to account for the existence of financing constraints but they do not find that it has a significant impact on the probability to innovate. In fact, the literature about innovation decisions stresses the role of firm's size as proxy to financial constraints (Cohen and Klepper, 1996). This can be explained by the importance of sunk costs linked to innovation investments. Large firms are more incited 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 investment activities in large firms which may enjoy larger cash-flows.

Other factors affecting the propensity to innovate have been emphasized by the literature. The impact of market structure on innovation is examined by several authors (Schumpeter (1942), Arrow (1962), Dasgupta and Stiglitz (1980), Aghion *et al.* (2002)). Schumpeter (1942) argues that a firm is incited to innovate if it enjoys a monopoly position because it would be worried about the entry of potential rivals. 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 recent 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 (measured by headcount innovations as well as patents). Thus, Aghion *et al.* (2002) propose a model with an inverted U-shape relationship between innovation and competition. In this model, competition may increase innovation profit margin but high competition may also reduce incentive to innovate for laggards. Concerning the firm's environment, Rosenberg (1974) argues that technological opportunities determine firm's 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. As a result, 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 across industries. The demand pull is another firm's environment factor

which may lead innovation (Schmookler, 1966). This approach identifies consumer's needs as driving new products or processes. From an empirical point of view, the main problem is to characterize the existence of technological opportunities and to define the latent demand. Empirical evidences of the role of the technologic push and of the demand pull are obtained by using qualitative indicators based on firm's own assessment (Barlet *et al.* (1998), Crépon *et al.* (1998, 2000)).

Now, let us present the datasets used to estimate the impact of financial constraints on firms' decision to innovate as well as some descriptive statistics.

3 Innovation, Financial Constraints and Balance Sheet Structure: a Brief Descriptive Analysis

3.1 Presentation of the datasets

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 survey we used, named "Financement de l'Innovation Technologique" (FIT) was conducted in 2000 by the French Ministry for 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 to know the financial amount of these projects. In addition, 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). The identification of firms that conduct an innovative project 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, had Your enterprise projects of new or significantly improved products or processes:

- *Which are not yet completed or not yet introduce to the market?*
- *Which were failures?*

We consider that a firm has undertaken innovative projects if it answered positively to at least one of these three questions.

In addition, the survey gives a qualitative information about the existence of

financial constraints. Firms were asked if they met obstacles that prevented them to lead or to undertake innovative projects. Among the obstacles listed in the survey, there are three expressions of the existence of financing constraints:[1]

- no financing source
- slowness in the setting up of the financing
- too high interest rate

We consider that a firm faced financial constraints for its innovative projects if it answered that it had projects which were delayed, abandoned or not started because of at least one of the three obstacles listed above.

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 Dataset. 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.

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[2].

3.2 Some Descriptive Statistics

The overall proportion of firms that can be considered to be innovative is, in our sample, 41.80%. These firms with innovative projects appear to suffer more often (proportionally) from financial constraints (about 25%) than do non-innovative firms (about 10%).

[INSERT TABLE 1 ABOUT HERE]

From table 3, we can notice that established firms having innovative projects are larger than the other ones and firms facing financing constraints seem to be smaller than unconstrained ones.

[INSERT TABLE 3 ABOUT HERE]

By looking at sector-based figures, we can see that the fraction of innovative/non-innovative firms as well as that of financially constrained/unconstrained firms vary a lot across manufacturing sectors.

[1] It is worth noticing that firms were allowed to tick more than one answer.

[2] 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 added value or with abnormally high investment rates have been excluded.

[[INSERT TABLE 2 ABOUT HERE]

The electrical and electronic equipment industry is characterized by the highest rate of innovative firms (68.02%) whereas the wood and wood products industry and the textile industry have the lowest (respectively 26.79% and 27.52%). These differences between manufacturing sectors are quite similar to those observed in terms of financial constraints. While, on average, 17.25 % of the firms suffer from financing constraints, this proportion amounts to 30.18% in the electrical and electronic equipment sector and to 27.68% in the transport equipment industry. It is only about 9% in the wood and wood products industry and around 11.11% in the leather industry, both industries being globally less innovative.

[INSERT TABLE 5 ABOUT HERE]

Concerning innovation expenditures, significant differences appear that seem to be linked to the existence of financial constraints[3]: firms facing financial constraints spend less for their innovative projects than unconstrained ones (three times less, in 1997, for instance, see table 5)[4]. The average firms' budget devoted to innovative projects shows important disparities across manufacturing sectors (table 6). Firms belonging to the manufacture of other non metallic mineral products spent on average about 1780 K€ in 1999 for their innovative projects, while firms manufacturing transport equipment or electrical and electronic equipment spent respectively about 7200 K€ and 13000 K€.

[INSERT TABLE 6 ABOUT HERE]

For the quasi-totality of financially constrained firms, the financing constraint simply lies in the absence of external financing sources (see table 4). 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).

[INSERT TABLE 4 ABOUT HERE]

In order to identify possible differences in the risk of each type of firm, we have examined the industry score constructed by the Banque de France (Bardos, 1998).

[3] The measure of the firm's innovation effort given by the survey includes not only R&D expenses but all budget devoted to innovative projects. This information is obtained thanks to responses to the following question: *What is Your budget devoted to the financing of Your innovative projects (whatever their progress), in 1997? in 1998?, in 1999?*

[4] Annual average innovation expenditures is calculated by taking into account size and sector effects by using variance analysis.

[5] Firms were allowed to provide multiple answers.

It is a composite indicator of company risk and consists of a linear combination of symptomatic ratios such as the profitability, solvency, debt and cash ratios. This indicator is constructed such as lower the score, the riskier the company's position and is used as a tool to establish an individual financial diagnosis.

[INSERT TABLE 9 ABOUT HERE]

Unlike Planès *et al.* (2002), we find significant differences concerning the risk of the firms which may seem quite surprising (Table 9): everything else being equal, innovative firms are less risky than non innovative ones. By considering the existence of financial constraints, a hierarchy in terms of risk can be established. The less risky firms appear to be those with innovative projects and being financially unconstrained; but at the same time, innovative firms facing financing constraints are riskier than unconstrained firms without innovative projects. Finally, the firms facing financing constraints and which do not undertake innovative project are the riskiest ones.

In order to try to understand this apparent paradox let us look whether there are differences in the firms balance sheet structure[6] depending on the possible existence of financial constraints and/or that of innovative nature (e.g. Planès *et al.* (2002)).

[INSERT TABLE 7 ABOUT HERE]

Investment significantly differs across each type of firm, especially as regards intangible investment[7] (table 7). As expected, innovative firms and particularly the financially constrained ones have a higher immaterial expenditures ratio (immaterial expenditures divided by value added). It amounts to 6.04% for constrained innovative firms and to 3.63% for non innovative unconstrained firms. Theses differences are mainly explained by the R&D expenditures. Larger immaterial expenditures for innovative firms may represent a risk factor which may induce some reluctance of external investors to bring funds.

Another interesting feature is the existence of an apparent hierarchy between each category of firms concerning their ability to earn profits. It may be established by various income ratios such as the gross operating profit margin, the share of financial fees in value added or the self financing capacity ratios (table 7). Not surprisingly, the firms which do not face 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.

A lot of papers about investment and financing constraints use the dividends distribution to discriminate between likely financially constrained firms and likely

[6] The descriptive statistics relative to corporate balance sheets are calculated by accounting for composition effects: in order to neutralize size and sector effects, the average variables for the four categories of firms are calculated through variance analysis.

[7] The French tax code states that companies are free to book operating expenditure for scientific or technical research either as fixed assets or as expenses. The Banque de France Sheet data Office separates off some items of the expenditure book as expenses, which makes it possible to reincorporate these expenditures within intangible investment. Nevertheless, it remains a part of the expenses, essentially outsourcing of R&D activities which are not reincorporated in immaterial expenditures.

unconstrained ones (for instance Fazzari and al., 1988). Our data are coherent with this idea: the share of dividends distribution in the value added of non constrained firms (5.21% for the innovative ones and 3.65% for the non innovative ones) is higher than the average ratio of the constrained firms (2.44% for the innovative firms and 2.58% for non innovative firms).

[INSERT TABLE 8 ABOUT HERE]

The financing structure confirms the significant differences between each type of firms in terms of financial reliability (Table 8). Own financing and financial debt are discriminating factors when comparing the innovation behavior and the financial constraints of the four categories 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 79.40% for unconstrained innovative firms and 67.60% for non innovative firms facing financial constraints. In the same way, financial debt represents only 20.60% of the total source of funds for innovative firms without financial constraints while it amounts to 32.40% for non innovative firms having financing constraints. By analyzing the financial debt's components, 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) and from the other extra-group financial debt, while the financing by the group (when relevant) does not appear significantly different between the categories of firms. For instance, the firms which undertake an innovative project and which do no have financial constraints use only 5.77% of their total source of funds as short term bank loans, whereas it represents 8.24% for constrained innovative firms and 13.98% for non innovative firms facing financial constraints.

Thus, as it was showed by Planès *et al.* (2002), innovative firms enjoy a better financial situation than non innovative ones, everything else being equal. This is consistent with the idea that there is a sort of selectivity concerning the decision to innovate for the firms which perform better (Bond *et al.*, 1999).

As a result, those basic statistics show that the four categories of firms have significantly different profiles. Innovative firms have the best results in terms of risk, financing structure and economic performances. Another type of firms includes the companies which do not want to innovate (and thus which do not face financial constraints for their innovative activities). Among the firms facing financial constraints, those which decide to undertake an innovative project present a better situation than those which do not engage into innovative activities.

Now, the following section proposes two econometric specifications in order to properly evaluate whether financing constraints affect firms' decision to innovate.

4 Econometric Results

Two specifications are used to model the role of financial factors in the decision to innovate: a simple probit model with exogenous financial constraints and a bivariate

recursive probit for the likely endogeneity of those financial constraints.

4.1 Innovation decisions with exogenous financial constraints

Following Crépon *et al* (1998, 2000), we first define a univariate probit where the decision of the firm to implement an innovative project depends on "traditional" determinants of the decision to innovate emphasized by the literature like the firm size, its market power, technological push and demand pull indicators. However, we supplement the model by adding financial variables to account for possible financial constraints: a dummy specifying the existence of financing constraints, the importance of own financing and of debt financing, the collateral value, the gross operating profit margin, etc.

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

$$y_{1i}^* = x_{1i}' a_1 + z_i' a_2 + u_i \tag{1a}$$

- where x_{1i} includes:
  - firm size measured as the logarithm of the number of employees, in order to allow for a non linear relationship;
  - firm market power measured as the share of the firm's sales in the total sales of the sector;
  - technology push indicators: the importance of technological opportunities is given by a qualitative measure issued from the FIT survey. The same indicator was used by previous works such as Crépon and al. (1998, 2000) or Barlet and 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 dummy variables TP2, TP3 and TP4 for the other levels. We expect a positive impact of these technologic push variables, increasing with the intensity of innovation opportunities in the sector.

    Unfortunately, the survey does not give information about the demand pull.
  - Industry dummies according to French classification NAF03[8]. The manufacture of electrical and electronic equipment is taken as reference. As we mentioned earlier, this sector is characterized by the highest percentage of innovative firms. We expect the coefficients of these dummies to be negative[9].

[8] This French classification is closed to the NACE.

[9] It would be interesting to know how past decisions about innovation and past financing constraints affect the present ones. Unfortunately, there are no available panel data with this information.

- and z_i include some of the following variables:
  - a binary variable specifying the existence of financing constraints for firm's innovative project; this variable is obtained thanks to the FIT survey,
  - the accounting financial variables of the firm obtained from the Banque de France Balance Sheet Dataset, *i.e.*,
    - the share of the banking debt,
    - the share of the own financing in the firm's total financing resources[10] These variables reflect firms' financing structure. A weak financing structure (*i.e.* small own financing ratio or high banking debt ratio) may induce financing constraints, and thus may hamper innovation.
    - the share of intangible assets in the firm's total balance sheet account for the collateral that the firm is able to provide to obtain banking loans.
    - the economic performance of the firm as measured by the gross operating profit margin ratio. A firm having low past profit margin may face financing constraints and then, may have difficulties to run innovative projects.

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.

The estimates of the likelihood of undertaking an innovative project obtained with the univariate probit are given in the next table.

[10] See variables definition in appendices (table 10).

Table 11. Probit specification

	Coeff.	Std.Err	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.
Constant	-2,511 ***	0,211	-2,511 ***	0,259	-2,612 ***	0,213	-2,612 ***	0,269
Size	0,322 ***	0,032	0,321 ***	0,033	0,330 ***	0,032	0,329 ***	0,033
Market share	-0,009	0,062	-0,024	0,063	-0,003	0,061	-0,021	0,063
TP4	1,763 ***	0,155	1,764 ***	0,155	1,656 ***	0,157	1,644 ***	0,158
TP3	1,246 ***	0,122	1,238 ***	0,122	1,189 ***	0,124	1,170 ***	0,124
TP2	0,819 ***	0,119	0,815 ***	0,119	0,774 ***	0,121	0,764 ***	0,121
Financial constraints	-	-	-	-	0,546 ***	0,086	0,629 ***	0,089
Banking debt	-	-	-0,002	0,002	-	-	-0,004	0,002
Own financing	-	-	0,000	0,002	-	-	0,001	0,002
Collateral	-	-	0,000	0,001	-	-	-0,001	0,001
Gross operating profit margin	-	-	0,005 ***	0,002	-	-	0,006 ***	0,002
DB	-0,506 ***	0,150	-0,500 ***	0,151	-0,473 ***	0,151	-0,456 ***	0,152
DC	-0,457 **	0,232	-0,481 **	0,233	-0,419 *	0,232	-0,460	0,233
DD	-0,356 *	0,211	-0,351 *	0,212	-0,310	0,213	-0,276	0,215
DE	-0,538 ***	0,135	-0,565 ***	0,136	-0,497 ***	0,137	-0,515 ***	0,138
DG	-0,265 *	0,159	-0,310 *	0,160	-0,201	0,160	-0,252	0,161
DH	-0,230	0,149	-0,246	0,150	-0,199	0,151	-0,202	0,152
DI	-0,258	0,168	-0,280 *	0,169	-0,267	0,170	-0,287 *	0,172
DJ	-0,303 ***	0,115	-0,307 ***	0,116	-0,288 **	0,116	-0,281 **	0,118
DK	0,239 *	0,133	0,237 *	0,134	0,267 **	0,134	0,273 **	0,135
DM	-0,049	0,164	-0,048	0,165	-0,042	0,167	-0,029	0,169
DN	-0,206	0,160	-0,218	0,160	-0,187	0,161	-0,202	0,161
Log likelihood fonctions	-1080.534		-1074.983		-1060.290		-1049.592	
R^2 Mac Fadden	0.180		0.185		0.196		0.204	
Number of firms	1940		1940		1940		1940	

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

The first column shows the results obtained with the same type of specification as Crépon *et al.* (1998). All significant estimates present the expected sign. We find that the probability of undertaking innovative projects increases with firm's size, with technology push indicators and that there are significant differences across sectors. However, according to our estimates, firm's market share does not have a significant impact on the likelihood of undertaking innovative projects, whereas Crépon *et al.* find a significant positive effect on the probability of engaging R&D.

In the second column, the estimates obtained by including variables reflecting the firms' financial conditions are reported. All ratios related to the *ex ante* financing structure are not significant. Only firm's economic results (defined by the operating profit margin ratio) have a significant positive effect on the probability of undertaking innovative projects. In the third column, the indicator of the existence of financing constraints taken from the survey is included as financial explanatory variable. While we expect a null or negative effect, we find a positive one. We do not obtain more satisfactory results by including together this qualitative indicator about financing

constraints and the accounting ratios (fourth column). Thus, this positive effect of financial constraints on the probability of undertaking innovative project is inconsistent with the theoretical literature about the impact of financing constraint on investment. Furthermore, it is noticeable that the estimates of the "traditional" determinants of innovation are not modified by including financial explanatory variables.

As a conclusion, this model is not satisfactory as it fails to account properly for financial variables as possible determinants of the decision to innovate. Indeed, there are many reasons to suspect that the decision of undertaking innovative projects and the probability of facing financing constraints are both affected by unobservable heterogeneity. The uncertainty associated with the output of the innovative project, the importance of the expenditure devoted to intangible investment and the eventual confidentiality of the project for strategic reasons are firm's specific risk factors which may create or worsen financial constraints. That is why we propose to use a recursive bivariate probit model (Greene, 1998). This specification allows to consider that financial constraints may be endogenous to the innovation decision.

4.2 Innovation decisions with endogenous financing constraints

Our recursive bivariate probit model aims at accounting for the likely endogeneity of the existence of financial constraints for a firm ($2b$) and of its decision to innovate or not depending on the existence of financial constraints ($2a$).

The latent model writes:

$$y_{1i}^* = x_{1i}'\beta_1 + \gamma y_{2i}^* + \varepsilon_{1i} \quad (2a)$$
$$y_{2i}^* = x_{2i}'\beta_2 + \varepsilon_{2i} \quad (2b)$$

where y_{2i}^* represents the (unobservable) severity of financial constraints. Thanks to the survey we use, we know whether or not the firm suffered from financial constraints. We observe:

$$y_{2i} = 1 \text{ if } y_{2i}^* \geq 0 \text{ and } y_{2i} = 0 \text{ otherwise.}$$

Thus, the estimated model is[11]:

$$y_{1i} = x_{1i}'\beta_1 + \gamma y_{2i} + \varepsilon_{1i} \quad (3a)$$
$$y_{2i} = x_{2i}'\beta_2 + \varepsilon_{2i} \quad (3b)$$

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

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

The factors x_{2i} explaining the probability of facing financing constraints are essentially the risk of the investment and the asymmetric informational problems with

[11] We do not introduce y_{2i} as explanatory variable in equation $2b$: Lewbel (2005) shows that coherency of simultaneous systems of binary choices requires the model to be recursive.

external investors. More precisely, we include the following variables in the financial constraints equation:

- The size of the firm is a widespread measure of information asymmetries. Large firm are more renowned, it is easier to obtain indications about their activities, about their performances or their managers education. Consequently, the size of the firm (measured by the log of the number of employees) is expected to have a negative impact on the probability of facing financing constraints.

- The importance of collateral value that a firm is able to engage to obtain a loan is another risk factor measured by external investors. It may be easier for firm with strong collateral value to borrow from external investors. Consequently, the collateral variable may have a negative impact on the probability of facing financing constraints.

- The importance of own financing is a positive indication concerning the financing reliability, whereas a too high financial debt seems as a weakness of the balance sheet structure. So, the two ratios related to the *ex ante* financing structure may have opposite effects on the probability of facing financing constraints: a negative one for the own financing ratio and a positive one for the bank loans ratio.

- Finally, we control for differences about risk across sectors by including sector dummies. Like for the innovation equation, we take the manufacture of electrical and electronic equipment as the reference. This sector presents the higher proportion of financially constrained firms. So, the sector dummies are expected to have negative signs.

From the econometric point of view, the endogenous nature of y_2 in the first equation does not modify the likelihood of the bivariate probit (Greene (1998, 2003). It is due to the fact that the joint probability (for instance $\Pr(y_1 = 1, y_2 = 1)$) which enters in the likelihood without endogeneity problem is equal to the product of the conditional and marginal probabilities ($\Pr(y_1 = 1|y_2 = 1) * \Pr(y_2 = 1)$ in the likelihood where y_2 is an endogenous explanatory variable for the first equation :

$$\begin{aligned} \Pr(y_1 &= 1, y_2 = 1) = \Pr(\ y_1 = 1|y_2 = 1) * \Pr(\ y_2 = 1) \\ &= \frac{\Phi_2\left(x_1'\beta_1, \gamma y_2, x_2'\beta_2, \rho\right)}{\Phi\left(x_2'\beta_2\right)} * \Phi\left(x_2'\beta_2\right) \\ &= \Phi_2\left(x_1'\beta_1, \gamma y_2, x_2'\beta_2, \rho\right) \end{aligned} \tag{4}$$

where Φ_2 is the cumulative distribution function of the bivariate normal distribution and $\Phi(.)$ is the univariate normal cumulative distribution function.

Then, in the recursive bivariate probit, the probabilities of each events:

- being innovative and financially constrained ($y_{1i} = 1, y_{2i} = 1$),
- being innovative and financially unconstrained ($y_{1i} = 1, y_{2i} = 0$),
- not being innovative but being financially constrained ($y_{1i} = 0, y_{2i} = 1$),
- not being innovative nor financially constrained ($y_{1i} = 0, y_{2i} = 0$)

are just given by the value of the bivariate normal cumulative distribution function, like in a standard bivariate probit model without endogeneity.

These probabilities are :

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

The correlation coefficient ρ between the disturbances accounts for the possible existence of omitted or unobservable factors which may affect simultaneously the decision to innovate and the likelihood of facing 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 of the coefficients.

The calculation of the marginal effects in the recursive bivariate probit model is shown in Green (1998). For a continuous variable which enters in both equations (for instance, firm's size), the total effect on the probability of undertaking innovative projects is the sum of a direct effect (due to $\Pr(y_1|y_2,x_1)$) and an indirect effect (through $\Pr(y_2|x_2)$).

For a qualitative variable the marginal effect is measured by the difference between the conditional probabilities. For example, the marginal effect of the existence of financing constraints on the likelihood of undertaking innovative projects is:

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

The likelihood of undertaking innovative projects and the probability of financing constraints have been estimated *i)* separately (table 12, column 1) and *ii)* simultaneously by allowing a correlation between the errors of the two equations (table 12, column 2).

Table 12. Innovation and financing constraints estimations (Full sample)

	Single equations		Bivariate probit	
	Coeff.	Std.Err.	Coeff.	Std.Err.
Index equation for undertaking innovative project(s)				
Constant	-2,612 ***	0,213	-2,102 ***	0,271
Size	0,330 ***	0,032	0,304 ***	0,034
Market share	-0,003	0,061	-0,003	0,055
TP4	1,656 ***	0,157	1,490 ***	0,168
TP3	1,189 ***	0,124	1,057 ***	0,132
TP2	0,774 ***	0,121	0,685 ***	0,119
Financial constraints	0,546 ***	0,086	-0,583 **	0,269
DB	-0,473 ***	0,151	-0,593 ***	0,147
DC	-0,419 *	0,232	-0,556 **	0,215
DD	-0,310	0,213	-0,494 **	0,208
DE	-0,497 ***	0,137	-0,623 ***	0,131
DG	-0,201	0,160	-0,380 **	0,163
DH	-0,199	0,151	-0,312 **	0,147
DI	-0,267	0,170	-0,323 *	0,167
DJ	-0,288 **	0,116	-0,371 ***	0,113
DK	0,267 **	0,134	0,144	0,136
DM	-0,042	0,167	-0,084	0,161
DN	-0,187	0,161	-0,317 *	0,165
Index equation for facing financing constraints				
Constant	-0,994 ***	0,239	-1,035 ***	0,230
Size	0,023	0,034	0,030	0,034
Banking debt ratio	0,010 ***	0,002	0,010 ***	0,002
Own financing ratio	-0,003 *	0,001	-0,003 ***	0,001
Collateral	0,004 ***	0,002	0,004 ***	0,002
Gross operating profit margi	-0,006 ***	0,002	-0,008 ***	0,002
DB	-0,595 ***	0,162	-0,571 ***	0,163
DC	-0,503 *	0,261	-0,479 **	0,236
DD	-0,881 ***	0,255	-0,909 ***	0,255
DE	-0,597 ***	0,150	-0,606 ***	0,150
DG	-0,701 ***	0,193	-0,683 ***	0,190
DH	-0,475 ***	0,163	-0,453 ***	0,162
DI	-0,291 *	0,175	-0,258	0,177
DJ	-0,434 ***	0,119	-0,420 ***	0,122
DK	-0,362 *	0,140	-0,327 **	0,141
DM	-0,224	0,171	-0,244 *	0,184
DN	-0,490 ***	0,174	-0,443 ***	0,171
Disturbance Correlation : rho			0,623	0,137
Log likelihood fonctions				
Innovation	-1060.290			
Constraints	-801.6491			
Bivariate model			-1854.634	
Number of firms	1940		1940	

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

The first striking result is the fact that we do get here a significantly negative impact of financial constraints on firms' propensity to be innovative. Indeed, the estimation of the bivariate probit shows a strong correlation between the error terms of the innovation and financial constraints equations ($\rho = 0,623$). Accounting for the endogeneity of the financial constraint, we obtain a spectacular change of the sign of the estimate associated with the financial constraints which becomes negative, 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 absolutely taken into account when we estimate the impact of financial constraints on firms' decision to innovate.

Moreover, as expected, the sector indicators show strong disparities in the probability of undertaking innovative projects across industries. In addition, the likelihood that a firm implements innovative activities raises with the importance of technological opportunities in its environment and with firm's size. According to our estimates, firms'market share does not affect their decision to implement technologically innovative projects whereas Crépon et al. (1998) find that it has a positive effect on the likelihood of undertaking R&D[12].

Finally, it is also worth noticing that the estimation of the likelihood of facing financial constraints also provides quite satisfactory results. Strong gross operating profit margin ratio as well as high own financing ratio reduce the probability of facing financial constraints while the banking debt ratio has a positive impact on the likelihood of being financially constrained. According to our estimates, firms' size does not determine the existence of financial constraints for established companies and industry dummies reveal significant differences across sectors. This result can be interpreted as reflecting the existence of significant differences concerning the risk of the various manufacturing sectors.

Table 13. Estimated marginal effects (at the sample means)

	Direct	Indirect	Total
Likelihood of undertaking innovative project(s)			
Size	0,1006	-0,0060	0,0946
Market share			
Financial constraints	-0,1928		-0,1928
TP4		0,4928	0,4928
TP3		0,3496	0,3496
TP2		0,2264	0,2264
Banking debt ratio		-0,0017	-0,0017
Own financing ratio		0,0004	0,0004
Collateral		-0,0007	-0,0007
Gross operating profit margin ratio		0,0013	0,0013

[12]The regression without firm's market share is presented in table 14 (column 1) : it does not modify all other estimated coefficients and standard errors.

4.3 Robustness

4.3.1 Sample definition

The survey we used gives information about financial constraints and other innovation obstacles :

- Excessive perceved economic risk
- Lack of qualified personnel
- Innovation costs too high
- Excessive get out clause in the shareholder agreement
- Lack of knowledge about ad hoc financial networks

Descriptive statistics concerning these hampering factors are reported in table 15.

[INSERT TABLE 15 ABOUT HERE]

By considering the existence of all innovation obstacles (both financial and non financial innovation hampering factors), the sample used may be devided into four types of firms :

- Firms which undertake innovative projects despite innovation obstacles
- Innovative firms without any innovation obstacles
- Firms encountering innovation obstacles which do not innovate
- Non innovative firms without any innovation obstacles

The first three categories are composed by potentially innovative firms whereas the last one contains firms which do not want to innovate (and so, which do not face financial constraints for innovative projects). In other words, only firms with innovative projects may face innovation obstacles. So, we decide to check if our estimates are modified by restricting our sample to potentially innovative firms. The results are presented in table 16. Globally, this estimation does not refute our previous conclusions. Moreover, it reveals that financial constraints and too high innovation costs are the only two significant innovation hampering factors listed in the survey. However, some differences are noticeable between the estimation based on the full sample and the other one run on just potentially innovative firms. Firstly, the market share has a positive effect on the likelihood that potentially innovative firms decide to implement innovative projects whereas it was not significant for the full sample. Secondly, concerning the financing constraints, large potentially innovative firms are significantly unlikely to face financing problems than smaller potentially innovative firms.

Table 16. Restricted sample: only potentially innovative firms

	Coeff.		Std.Err.
Index equation for undertaking innovative project(s)			
Constant	-0,328		0,384
Size	0,238	***	0,060
Market share	0,622	***	0,241
TP4	1,216	***	0,237
TP3	0,769	***	0,188
TP2	0,373	***	0,180
Financial constraints	-1,261	***	0,259
Excessive economic risk	-0,132		0,094
Lack of qualified employees	-0,064		0,095
Innovation costs too high	-0,387	***	0,095
Excessive get-out clause	-0,227		0,244
Lack of knowledge about financing	0,304		0,191
Index equation for facing financing constraints			
Constant	0,266		0,324
Size	-0,080	**	0,040
Banking debt ratio	0,007	**	0,003
Own financing ratio	-0,011	***	0,003
Collateral	0,003		0,002
Gross operating profit margin ratio	-0,010	***	0,002
Disturbance Correlation : rho	0,565	***	0,166
Log likelihood fonctions	-1073.582		
Number of firms	1082		

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

Estimated with a bivariate probit and 12 industry dummies

4.3.2 Firm's size : Are medium size firms more affected by financing problems?

In our previous regressions, firm's size is measured by a continue variable (the logarithm of the number of employees) while only firms with a specific size may face financing constraints. In particular, Passet and Du Tertre (2005) argue that financing constraints may be particularly relevant for medium size firms. They emphasized that the French state expenditure on R&D is focused on large and small firms. On the one hand, large firms benefit from state orders, essentially for military defense or through important technology programs. On the other hand, small firms may use subsidized loans or advances which have to be paid off only if the project becomes successful. In addition, young innovative firms may enjoy an attractive fiscal pol-

icy[13]. Thus, medium size firms are relatively neglected by the public expenditure for innovation.

To check for this possibility, we define three categories to characterize firm's size:
- small size (less than 100 employees)
- medium size (between 100 and 500 employees)
- large size (more than 500 employees)

We take small size as reference. The estimates are in table 17.

[INSERT TABLE 17 ABOUT HERE]

This discrete measure of firm's size does not reveal a specific financing problem for medium size firms: the dummy variable is non significant.

4.3.3 Firm's collateral and the role of the group affiliation

It is particularly difficult to define innovative firm's collateral. We used the share of tangible assets in the firm's total assets but tangible assets may be firm's specific due to the firm's innovative character. Thus it may be a poor measure of firm's collateral which may biaised the coefficient and explained its unexpected positive sign in the financing constraint equation.

We explore an alternative measure of firm's ability to repay its creditors: a dummy variable identifying whether the firm belongs to a group or not. The head of group may provide guarantees for its subsidiary companies. Thus, from the creditors' point of view, subsidiary companies may offer more guarantees than independent firms. Another argument for taking into account firm's membership of a company group is the possible role of financing from the head of group. These financing source may weaken the need for external funds and may reduce firm's probability of facing financing constraints for its innovative projects. Thus, we introduce this dummy variable identifying whether the firm belongs to a group or not. Nevertheless, according to our estimates (table 18), the group affiliation have no significant effect on firms' financing constraints for innovation.

[INSERT TABLE 18 ABOUT HERE]

5 Conclusion

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

This paper shows that the likelihood that a firm will implement innovative projects is significantly reduced by the existence of financial constraints. Moreover, we obtain the traditional results: firm's size and market share have a positive effect on the decision to innovate. The propensity to innovate also depends on firm's environment. In addition, we find that the likelihood that a firm faces financial constraints is

[13]The french legal status "Jeune entreprise innovante" (Young innovative firm) allows to enjoy tax exemption.

explained by its *ex ante* financing structure, by its past economic performances and by sector-based factors. We show that the likelihood to innovate and the probability of facing financial constraints are simultaneously affected by unobservable heterogeneity. Then a standard univariate probit model fails to provide consistent estimates of the impact of financial constraints on the probability of undertaking innovative projects while a recursive bivariate probit model does solve this problem.

References

[1] Aghion P., Bloom N., Griffith R., Howitt P., Blundell R. (2002), "Competition and Innovation : An Inverted U Relationship", *NBER Working Paper* n°*W*9269.

[2] Arrow K.J. (1962), "Economic Welfare and the Allocation of Resources for Innovation", in: Universities-National Bureau Committee for Economic Research, *The Rate and Direction of Inventive Activity*. Princeton.

[3] Bardos M. (1998), "Detecting the Risk of Company Failure at the Banque de France", *Journal of Banking & Finance*, 22, 1405-1419.

[4] Barlet C., Duguet E., Encaoua D., Pradel J. (1998), "The Commercial Success of Innovations: An Econometric Analysis at the Firm Level in French Manufacturing", *Annales d'Economie et de Statistique*, n°49/50, 457-478.

[5] Bond S., Harhoff D., Van Reenen J. (1999), "Investment, R&D, and Financial Constraints in Britain and in Germany", *IFS working paper*, n° 99/5.

[6] Blundell R., Griffith R., Van Reenen. (1999), "Market Share, Market value and Innovation in a Panel of British Manufacturing Firms", *Review of Economic Studies*, 66, 529-554.

[7] Cohen W.M., Klepper S. (1996), "A Reprise of Size and R&D", *The Economic Journal*, 106, 925-951.

[8] Cohen W.M., Levin R.C (1989), "Empirical Studies of Innovation and Market Structure", in R. Schmalensee and R.D Willing, *Handbook of Industrial Organization*, North-Holland, chapter 18, 1060-1107.

[9] Crépon B., Duguet E., Mairesse J. (1998), "Research, Innovation and Productivity: An Econometric Analysis at the Firm Level", *Economics of Innovation and New Technology* 7, 115-158.

[10] Crépon B., Duguet E., Mairesse J. (2000), "Mesurer le Rendement de l'Innovation", *Economie et Statistique*, n°334, 65-78.

[11] Dasgupta P., Stiglitz J.E.(1980), "Industrial Structure and The Nature of Innovative Activity", *The Economic Journal*, 266-293.

[12] Fazzari S.M, Hubbard R.G., Petersen B.C. (1988), "Financing Constraints and Corporate Investment", *Brookings Papers on Economic Activity*, 141-195.

[13] Greene W.H. (1998), "Gender Economic Courses in Liberal Arts Colleges: Further Results", *Journal of Economic Education*, 291-300.

[14] Greene W.H. (2003), *Econometric Analysis*, Fifth Edition, Prentice Hall

[15] Hall B. H. (2002), "The Financing of Research and Development", *Oxford Review of Economic Policy*, vol 18, n°1, 35-51.

[16] Harhoff D. (1998), "Are There Financing Constraints for R&D and Investment in German Manufacturing Firms", *Annales d'Economie et de Statistique*, n°49/50, 421-456.

[17] Harris M., Rogers M., Siouclis A. (2003), "Modelling Firm Innovation Using Panel Probit Estimators", *Applied Economic Letters*, vol. 10(11), 683-686.

[18] Jensen M.C, Meckling W.H. (1976), "Theory of the Firm : Managerial Behavior, Agency Costs and Ownership Structure", *Journal of Financial Economics*, 305-360.

[19] Janz N., Peters B. (2002), "Innovation and Innovation Success in the German Manufacturing Sector, Econometric Evidence at the Firm Level", *Manuscript.*

[20] Janz N., Lööf H., Peters B. (2003), "Firm Level Innovation and Productivity : Is there a Common Story Across Countries?", *ZEW Discussion Paper* n°03-26.

[21] Kaplan S.N, Zingales L. (1997), "Do Investment-Cash Flow Sensivities Provide Useful Measures of Financing Constraints?", *Quarterly Journal of Economics*, February, 169-215.

[22] Kaplan S.N, Zingales L. (2000), "Investment-Cash Flow Sensitivities Are Not Valid Measure of Financing Constraints", *NBER Working Paper* n°7659.

[23] Lööf H. and Heshmati A. (2002), "On the Relationship between Innovation and Performance: A sensitivity Analysis" *Working Paper Series in Economics and Finance* 0446, Stockholm School of Economics.

[24] Lewbel (2005), "Coherency of Structural Models Containing a Dummy Endogeneous Variable", *Boston College Working Papers in Economics* n°456.

[25] Mairesse J., Hall B.H, Mulkay B.(1999), "Firm-Level Investment in France And The United States: An Exploration of What We Have Learned in Twenty Years", *Annales d'Economie et de Statistique*, n°55-56, 27-63.

[26] Mohnen P., Therrien P. (2002), "Comparing the Innovation Performance of Canadian Firms and those of Selected European Countries: An Econometric Analysis", CIRANO, *Scientific Series*, 2002s-80

[27] Mulkay B., Hall B.H, Mairesse J. (2001), "Firm Level Investment and R&D in France and in the United States", in Deutsche Bundesbank (ed), *Investing Today for the World of Tomorrow*, Springer Verlag.

[28] Myers S. et Majluf N. (1984), "Corporate Financing and Investment Decisions When Firms Have Information that Investors Do Not Have", *Journal of Financial Economics*, 13, p. 187-221.

[29] OECD and Eurostat (1997), *Oslo-Manual, Proposed Guidelines for Collecting and Interpreting Technological Innovation Data*, Organization for Economic-Co-Operation and Development, Paris.

[30] Passet O., Du Tertre R. (2005), "Promouvoir un environnement financier favorable au développement de l'entreprise", Rapport du groupe de projet Astypalea, Commissariat Général du Plan.

[31] Planès B., Bardos M., Avouyi-dovi S., Sevestre P.(2002), "Financing Innovative Industrial Firms : Risk and Financial Constraints", *Banque de France Bulletin Digest*, n°104, August.

[32] Rosenberg N. (1974), "Science, Invention and Economic Growth", *Economic Journal*, 84, 90-108.

[33] SESSI, (2002), *Le financement de l'innovation technologique dans l'industrie*, Référence-Chiffres clés, n°217.

[34] Schmookler J. (1966), *Invention and Economic Growth*, Cambrige, Harvard University Press.

[35] Schroth E., Szalay D. (2004), "Cash breeds Success: The Startegic Role of Financing Constraints in Innovation", Working paper, FAME.

[36] Schumpeter J.A. (1942), *Capitalism, Socialism, and Democracy*, New York, Harper.

[37] Stiglitz J., Weiss A., (1981), "Credit Rationing in Markets with Imperfect Information", *American Economic Review*, 393-410.

[38] Williamson S.D. (1987), "Costly Monitoring, Loan Contracts, and Equilibrium Market Rationing", *The Quarterly Journal of Economics*, February, 135-145.

[39] Willimason O. (1988), "Corporate Finance and Corporate Governance", *Journal of Finance*, 43, 567-591.

6 Appendices

6.1 Description of the sample

Table 1: Number of firms in the sample

	Constrained	Unconstrained	Total
Firms with innovative project(s)	198	613	811
Firms without innovative projects	112	1017	1129
Total	310	1630	1940

Table 2: sample composition

	Industry	Number of firms (in the sample)	% of firms with innovative projects (within the sector)	% of financially constrained firms (within the sector)
DB	Textiles and textile products	155	27.52	12.08
DC	Leather and leather products	45	28.89	11.11
DD	Wood and wood products	59	26.79	8.93
DE	Pulp, paper and paper products, publishing and printing	211	29.44	12.18
DG	Chemicals industry	121	58.41	11.5
DH	Rubber and plastics	139	43.28	14.93
DI	Other non-metalic mineral products	101	43.75	17.71
DJ	Basic metals and fabricated metal products	458	37.81	17.00
DK	Machinery and equipment	213	65.4	17.54
DL	Electrical and electronic equipment	218	68.02	30.18
DM	Transport equipment	102	64.29	27.68
DN	Other manufacturing industries	118	41.69	12.04
	All sample	1940	45.93	17.25

Table 3: Firms'size (Number of employes)

	Firms with innovative projects		Firms without innovative projects	
	Constrained	Unconstrained	Constrained	Unconstrained
Mean	313.23	357	137.47	149.17
Lower Quartile	60	74	39.5	42
Median	146.5	175	70.5	77
Upper Quartile	441	520	145.5	155

Table 4: The financial constraints

	% of 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

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.

6.2 Variance analysis

Table 5: Annual average innovation expenditures (in K€)

Years	Firms with innovative projects		
	Constrained	Unconstrained	
1997	2900.835	9386.821	(***)
1998	2811.828	6494.917	(**)
1999	2697.135	7466.807	(***)

Variance analysis taking into account sector and size effects
*/**/*** indicates significant difference at the 10%/5%/1% level whether or not firms face financial constraints.

Table 6: Annual average innovation expenditures (in K€) by industry

	1997	1998	1999
DB	4970.328	3753.921	3934.659
DC	4016.185	2799.511	3346.852
DD	6069.428	4915.130	5321.525
DE	4943.931	4000.871	4416.574
DG	7430.866	7896.370	8953.225
DH	4681.522	3934.456	4337.774
DI	1847.233	1501.313	1779.080
DJ	3752.227	3063.623	3055.896
DK	3758.342	2942.658	3590.497
DL	10775.139	11608.134	13015.432
DM	18475.680	7074.325	7206.412
DN	3005.059	2350.157	2025.726

Variance analysis taking into account financing constraints and size effects

Table 7: Ratios (% of added value)

	Firms with innovative projects		Firms without innovative projects	
	Constrained	Unconstrained	Constrained	Unconstrained
Immaterial expenditures	6.042	4.669	3.848	3.633
of which R&D	2.667	1.392	0.937	0.88
Gross operating profit margin	15.117	23.004	6.062	18.321
Financial fees	5.216	3.274	5.511	3.469
Self financing capacity	12.771	17.338	2.014	14.157
Dividends distribution	2.440	5.207	2.583	3.653

Average ratio calculated by using variance analysis for a given size and industry
All calculated means are significantly different according to firms'type at the 1% level

Table 8. Firms financing structure

	Firms with innovative projects		Firms without innovative pro	
	Constrained	Unconstrained	Constrained	Unconstrained
Own financing (***)	73.949	79.402	67.601	76.963
Market financing	0.169	0.335	0.255	0.258
Financial debt (***)	26.051	20.598	32.398	23.065
Details of the financial debt:				
Bank loans (***)	16.102	12.557	22.493	14.655
- Long-term bank loans (*)	7.863	6.816	8.510	7.409
- Short-term bank loans (***)	8.239	5.741	13.984	7.246
Financing by group companies and related entities	7.148	5.453	5.543	6.065
Other extra-group financial debt (***)	2.534	2.246	4.084	2.064

% of total resources

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

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

Table 9: Average composite indicator of company risk (source : Banque de France)

	Constrained	Non constrained
With innovative project	0.505	1.169
Without innovative project	0.043	0.883

Variance analysis taking into account sector and size effects.

Calculated means are significantly different at the 1% level according to firms 'type.

6.3 Definitions

Table 10: Definition of variables

Name	Type	Definition
Financial constraints	Discrete	=1 if the firm face financial constraints,=0 otherwise
Size	Continue	log (number of employees)
Small Size	Discrete	=1 if there is less than 100 employees, =0 otherwise (referer
Medium Size	Discrete	=1 if there is between 100 and 500 employees, =0 otherwise
Large Size	Discrete	=1 if there is more than 500 employees, =0 otherwise
Market share	Continue	$\frac{\text{sales of the firm}}{\text{sales of the sector}} \times 100$
Banking debt ratio	Continue	$\frac{\text{Banking debt}}{\text{(Own financing+Market Financing+Financial debt)}} \times 100$
Own financing ratio	Continue	$\frac{\text{Own financing}}{\text{(Own financing+Market Financing+Financial debt)}} \times 100$
Gross operating profit margin	Continue	$\frac{\text{EBDIT}}{\text{Added value}} \times 100$
Collateral	Continue	$\frac{\text{tangible asset+stocks}}{\text{Total assets}} \times 100$
Technology push :	Discrete	
TP1		=1 if firm's market is technologically not innovative (mode of reference)
TP2		=1 if firm's market is technologically weakly innovative,
TP3		=1 if firm's market is technologically moderately innovative
TP4		=1 if firm's market is technologically strongly innovative
Sector indicators	Discrete	
Groupe	Discrete	=1 if the firm belongs to a company group, =0 otherwise

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

Table 14. Alternative specification (full sample)

	Coeff.		Std.Err.	Coeff.		Std.Err.	Coeff.		Std.Err.
Index equation for undertaking innovative project(s)									
Constant	-2,099	***	0,267	-2,071	***	0,270	-2,053	***	0,281
Size	0,304	***	0,032	0,297	***	0,032	0,294	***	0,032
Market share	-		-	-		-	-		-
TP4	1,490	***	0,168	1,495	***	0,168	1,492	***	0,171
TP3	1,057	***	0,132	1,061	***	0,132	1,058	***	0,135
TP2	0,685	***	0,119	0,688	***	0,119	0,683	***	0,121
Financial constraints	-0,583	**	0,269	-0,568	**	0,273	-0,577	**	0,287
Index equation for facing financing constraints									
Constant	-1,035	***	0,230	-0,881	***	0,150	-0,554	***	0,103
Size	0,030		0,034	-		-	-		-
Banking debt ratio	0,010	***	0,002	0,009	***	0,002	0,009	***	0,002
Own financing ratio	-0,003	***	0,001	-0,003	***	0,001	-0,003	***	0,001
collateral	0,004	***	0,002	0,004	***	0,002	-		-
Gross operating profit margin ratio	-0,008	***	0,002	-0,008	***	0,002	-0,008	***	0,002
Disturbance Correlation : rho	0,623	***	0,137	0,615	***	0,139	0,617	***	0,146
Log likelihood fonctions	-1854.636			-1855.041			-1859.427		
Number of firms	1940			1940			1940		

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

Estimated with a bivariate probit and 12 industry dummies

Table 15. Non financial obstacles: Descriptive statistics

	% potentially innovative firms with	% potentially innovative firms facing financial constraints and:
Financial constraints	29,59	100
Excessive perceived economic risk	41,96	48,96
Lack of qualified personnel	37,01	52,54
Innovation costs too high	47,17	70,75
Excessive get out clause	5,57	17,61
Lack of knowledge about ad hoc financial network	7,77	22,39

Table 17 . Firm's size: qualitative variable

	All sample		Only potentially innovative firms	
	Coeff.	Std.Err.	Coeff.	Std.Err.
Index equation for undertaking innovative project(s)				
Constant	-0,896 ***	0,199	0,330	0,240
Large size	0,878 ***	0,110	0,578 ***	0,212
Medium size	0,360 ***	0,068	0,312 ***	0,101
Market share	0,022	0,047	0,788 ***	0,248
TP4	1,508 ***	0,172	1,227 ***	0,230
TP3	1,050 ***	0,134	0,786 ***	0,183
TP2	0,686 ***	0,120	0,379 ***	0,172
Financial constraints	-0,636 **	0,275	-1,381 ***	0,250
Index equation for facing financing constraints				
Constant	-0,608 ***	0,118	0,149	0,173
Large size	0,107	0,115	-0,203	0,133
Medium size	0,039	0,079	-0,086	0,097
Banking debt ratio	0,009 ***	0,002	0,007 **	0,003
Own financing ratio	-0,003 ***	0,001	-0,011 ***	0,003
Gross operating profit margin ratio	-0,008 ***	0,002	-0,010 ***	0,002
Disturbance Correlation : rho	0.646		0.569 ***	0.164
Log likelihood fonctions	-1867.355		-1090.849	
Number of firms	1940		1082	

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

"Small size" is the mode of reference

Estimated with a bivariate probit and 12 industry dummies

Table 18. The role the group affiliation

	All sample				Only potentially innovative firms			
	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.
Index equation for undertaking innovative project(s)								
Constant	-2,078 ***	0,279	-2,100 ***	0,271	-0,505	0,366	-0,485	0,364
Size	0,302 ***	0,034	0,304 ***	0,034	0,224 ***	0,057	0,222 ***	0,057
Market share	-0,002	0,055	-0,003	0,055	0,635 ***	0,243	0,629 ***	0,242
TP4	1,480 ***	0,170	1,489 ***	0,168	1,202 ***	0,229	1,193 ***	0,228
TP3	1,049 ***	0,135	1,056 ***	0,132	0,775 ***	0,182	0,767 ***	0,181
TP2	0,676 ***	0,120	0,684 ***	0,119	0,375 **	0,173	0,372 **	0,171
Financial constraints	-0,610 **	0,277	-0,587 **	0,268	-1,371 ***	0,249	-1,400 ***	0,240
Index equation for facing financing constraints								
Constant	-0,764 ***	0,213	-1,038 ***	0,230	0,475	0,287	0,239	0,321
Size	0,039	0,035	0,031	0,035	-0,075 *	0,041	-0,079 *	0,041
Groupe	-0,098	0,195	-0,025	0,199	-0,057	0,218	-0,013	0,223
Banking debt ratio	0,009 ***	0,002	0,010 ***	0,002	0,006 **	0,003	0,007 **	0,003
Own financing ratio	-0,003 ***	0,001	-0,002 ***	0,001	-0,011 ***	0,003	-0,010 ***	0,003
Collateral	-	-	0,004 ***	0,002	-	-	0,003	0,002
Gross operating profit margin ratio	-0,008 ***	0,002	-0,008 ***	0,002	-0,010 ***	0,002	-0,009 ***	0,002
Disturbance Correlation : rho	0,635 ***	0,141	0,625 ***	0,136	0,566 ***	0,163	0,587 ***	0,158
Log likelihood fonctions	-1858.712		-1854.626		-1088.168		-1086.934	
Number of firms	1940		1940		1082		1082	

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

Estimated with a bivariate probit and 12 industry dummies