Innovation and the Quality of Labour Factor: An Empirical Investigation in the French Food Industry

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ABSTRACT. The aim of our paper is to analyse the determinants of the innovation propensity of the firm. Among the numerous works devoted to this subject, the interest of our research is, firstly, to use a direct measurement of innovation, instead of the usual proxies, as R&D expenditures and patents statistics, secondly, to emphasise the role of labour factor quality as a major determinant of innovation. We first build a definition of labour factor quality, based on a double dimension: individual skill level and functional distribution of jobs inside the firm. At the end we consider that each job category can be involved in the innovation process, at the different steps of it: conception, decision, implementation. To explain the innovation propensity at the firm level, our logit model takes into account four explanatory dimensions: the quality of labour factor employed inside the firm, the firm structural characteristics (as size, for instance), the sectoral market structures and, finally, the quality of labour factor employed inside the firm sector, as a proxy for the R&D spillover effect. We use some individual firms data, including a direct measurement of innovation, that distinguished between several types: radical vs. incremental and product vs. process vs. organisational innovation. The French food industries with its 500.000 employees and 42 sectors, mostly composed of small firms, are our empirical field. The results emphasise the influence of the usual firm structure variables. Firm size, particularly, is very clearly positively related to the innovation propensity. At the same time, some more original facts appears, such as the influence of firm status: after controlling the sectoral influence, co-operative firms seem to innovate less than private ones. Labour factor quality appears to play a very significant role by itself, but mostly, helps us to analyse and specify the influence of other variables on innovation. At the end, it shows that innovation is a multiphase process, and that the relative importance of each phase greatly depends on the kind of innovation that is considered. Conception is the most important phase in the radical innovation case, which greatly involves formally high-skilled job categories as R&D employees or engineers. At the same time, the implementation phase, which seems to be particularly important in the incremental innovation case, emphasises the role of the intermediate categories know-how.

At the end we can say that small industrial firms appear to be less innovative for two reasons: the usual scale effect argument is correct only in the process innovation case in relation to the capital intensity level. In some other cases as radical innovation, small firms are less innovative because of their job structure and particularly because of the lack of formal scientific capabilities (as the R&D personnel's one).

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Our aim: the determinants of innovation at the firm level

What is innovation and where does it come from? A huge amount of work has been devoted to these two complementary questions. This paper tries to add one more brick to that wall, by studying the determinants of innovation at the firm level with some specific interest related to the definition and measurement of innovation and to the choice of its determinants.

Some well-known definition of innovation can be found in the theoretical literature and, first of all, in Schumpeter's work (Schumpeter, 1912, 1942). The problem mainly appears with the measurement of it. People are often conducted to use proxies as R&D expenditures (Griliches, 1994) (that is nothing but an input of innovation) or patents statistics (Griliches, 1990) (that is some output of innovation). We here get some direct measurement of innovation, stated at the firm level, consistent with Schumpeter's approach.

A second interest of this paper is the choice of innovation determinants. A lot of these have been clearly identified in the literature (Cohen and Levin, 1989). Some concern the firm itself, some others express spillover effect issued from other firms. We try to keep both of these and use them

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in the best way. However we also propose to introduce a new major explanatory dimension related to what we call the "labour factor quality".

According to that, the paper will use the following plan. We first recall what are the variables that are usually considered as innovation main determinants. In a second part, we specify our definition of labour factor quality before we include it in a general innovation propensity model. This model will then be estimated by the use of individual firms data of the French Food Industry. The results relative to the different kinds of innovation will be then successively examined. During all these developments, a specific attention will be given to small firms that mostly compose this sector, and moreover to the relationship between size and innovation.

I. Our theoretical and analytical frame

We can start from the Schumpeter's well-known definition of innovation, or, more precisely of "New combinations of productive means" (Schumpeter, 1912, p. 66). This does not only provide us with a formal definition of innovation, but also leads to identify a certain number of its determinants. Some of them directly concern the firm structure, as the size effect, whilst others are external to it, as market structure characteristics, or spill-over effect. We recall these usual factors in a first part, but we think that an other explanatory dimension, the labour factor, has been unconsidered. We shall explain in a second part why and how that factor plays a major role, both as an internal and external variable.

I.1. *Innovation: the usual determinants*

What are the determinants of innovation? So much work is devoted to that question that we need to organise and classify the answers.

Firm variables: the size effect

The size of a firm has been traditionally considered as one of the most important determinants of its propensity to innovate, and many empirical tests have been devoted to this question. However their empirical results are not entirely satisfying and the existence of a strong and positive linear (or log-linear) relationship is not clearly and systematically proven. The Cohen and Levin's survey (1989) pointed out that, in the sixties, several authors, as Mansfield (1968) do not obtain more than a very thin correlation, by using R&D expenditures as a proxy for innovation input. Later, other work (Loeb, 1987), using patents as a proxy for innovation output, emphasise the existence of a strong and positive relationship. At the same time, other authors, as Scherer (1982), were not able to conclude on that point. More recently, B. Crépon (1993), operating with individual French firms data, has obtained very strong results that indicate the existence of a strongly positive correlation, without any apparent threshold effect.

The disturbing variety of these results can be partly explained by the empirical context: the nature of the relation between innovation and firm size depends on the sectoral, geographical or temporal area that is considered. It can also be explained by some methodological considerations as the choice of indicators to measure innovation. A bias results from the use of proxies such as R&D expenditures or patent statistics and, moreover, this bias depends itself on the size of the firm. Thus, we can assume that innovation is more closely linked to R&D and leads more often to patent outputs in the case of large firms, as shown by Kleinknecht (1987).

However, beyond this, we need to go back to a stimulating reflection on our theoretical and analytical scheme.[1] What expresses the size of a firm? Certainly more than a single dimension. Technical dimension is of course concerned with the return to scale effect, but also the organisational dimension: the way the firm is organised in terms of hierarchy, co-operation, information circulation . . . strongly depends on its size. We could even consider size as an indicator of the seniority of the firm.[2] Because the relationship between size and the innovation propensity expresses all these different and perhaps conflicting dimensions, it can take different forms,[3] and the specification of a single relation, common to firms of different sectors does not make sense. More than theoretical speculation, all this leads to complete (and to control, in the econometric sense) the size effect with some others variables in order to specify it. This will be one of the major reasons why we introduce labour factor quality in the next part, but, before that, we have to take into account some other variables. Capital intensity as well as the sectoral classification seem to be some good indicators in order to specify the technical dimension of the productive activity. At the same time, we can use an interesting variable related to the organisational dimension, which is the institutional status. As a matter of fact, a significant part of our sample is composed of co-operative firms, and it seems interesting to observe if their innovation propensity differs of those of the private firms.

External variables: the market structures

Some other facts can be taken into account in order to analyse the innovation propensity of the firm and even to specify the relationship with size. If we now consider market structures, we are again faced with a large number of empirical papers. Most of them, as Scherer (1967) or Bozeman and Link (1983), pointed out a positive link between innovation and industrial concentration, a result which is consistent with Schumpeter's approach, arguing that market power is a positive fact for innovation. However Z. Acs and D. Audretsch (1990), using for the first time a direct measurement of innovation, show that innovation activity is not promoted, but inhibited, in highly concentrated industries. Concerning the respective roles of small and large firms, these authors suggest that large ones have innovative advantage in industries that are capital-intensive and advertising-intensive, while innovative advantage of small firms exists in industries that are highly innovative and that use a high component of skilled labour.

External variables: the spill-over effect

It is now generally admitted that even the firms that do not execute R&D themselves can capture positive externalities from knowledge produced by other firms.[4] A good way to study and measure this effect would be to carefully observe the knowledge diffusion channels, through the role of intermediate agents as R&D public laboratories, for instance. However our lack of information conducts us to only measure the R&D knowledge that can be potentially captured inside of sector. This will be allowed with the introduction, in the following part, of labour factor quality variable.

I.2. *Labour factor as a major determinant*

The assumption that the human factor is a major determinant of innovation is not a new one. Thus everybody knows the role of the "entrepreneur-innovateur" as a main figure of Schumpeter's books. However, it seems to us an insufficient answer to consider the single effect of a particular category while forgetting all the others. thus we suggest a more complete approach based on the study of the contributions of all the different categories of employees, founded on what we call the "labour factor quality".

We define that notion in a previous work (Huiban, 1994). The firm employment can be divided into a certain number of elementary job categories, based on a double dimension: the individual skill level of the job and the functional distribution of employment inside of the firm. Finally this appears to be both an individual and a collective definition: the quality depends on the individual capabilities but also on the way they are organised in the firm. This permits us to take into account the technical dimension but also the organisational one.[5]

So, we can write:

$$\mathrm{L} = \sum_{f=1}^{F} \sum_{s=1}^{S} L_{fs}$$

with L_{fs} the job category corresponding to the skill level s (s = 1 to S), employed to the function f (f = 1 to F).

How can labour factor quality, as previously defined, influence the firm's innovation process? We have first to precise our analytical representation of innovation process in order to explain which job categories are concerned and how they are. More precisely, we can distinguish between three different periods in the innovation process:

– a conception phase, closely linked to R&D activity or, at least, to the kind of activities that need formal knowledge and abstraction capabilities. Several job categories are concerned: we can think of some high formally skilled categories, operating in functions for which innovation constitutes a natural and explicit goal, as R&D people, engineers and technical managers . . . ;

– A decision phase, that occurs when the possibility of innovation is technically established. Here is the question: to implement or not? This phase is both a hierarchical and informational one, that involves people that can compare costs and anticipated benefits and that must take the decision: managers are directly concerned;
– an implementation phase, where academic knowledge leaves place to the concrete know-how of the firm and its activity. Some categories, such as technicians, hierarchical intermediate categories or skilled workers, for whom innovation does not represent the main task but a kind of indirect production, are concerned. Moreover, if we want to give to the notion of innovation a larger sense than the strictly technical one and thus to consider other dimensions such as organisation, marketing . . . we have to include in our test the job categories that are functionally concerned with these kinds of activity, as sales or administrative categories.

The previous scheme can be of course criticised, first by saying that the innovation process is not a linear one and also includes many feedback's (Kline and Rosenberg, 1986). The different phases are empirically deeply overlapped. Secondly, the importance of each step depends dramatically on the kind of innovation that is considered. For instance, the two first ones will be of greater importance in the case of a radical innovation. At the same time, the concerned job categories also differ. We can illustrate this, by assuming that there is a strong relationship between, on the one hand, a non-transferable human capital (that we could call specific knowledge) associated to local incremental innovations and, on the other hand, a mainly transferable human capital (based on the owning of academic and scientific knowledge) and radical innovation.

Labour factor quality can also provide us with a measurement of spillover effect. Because, we do not get any data to observe the concrete diffusion of innovation, we suggest to take into account the average part of R&D personnel in the sectoral employment. It seems thus plausible to assume that this is a good indicator of the stock of formal and generic knowledge related to the same kind of activity (or to a close one). It is then acceptable to consider that this particular kind of knowledge is the most easy to transfer from firm to firm inside of a sector.

II. The innovation propensity and its determinants: our model[6]

Our model has to explain the differences observed between individual firms from the innovation point of view. Its specific interests are to use a direct measurement for innovation, and then to introduce the effect of labour factor quality, while it keeps a dual presentation distinguishing between firm variables and sectoral variables.

A direct measurement of innovation
We use a direct measurement for innovation, by using the French survey "ITI" (for "Innovation Technologique dans l'Industrie"), conducted in 1990 (Ministere de l'Industrie, 1994). Thus, we can avoid the use of typical proxies as R&D expenditures[7] or patents statistics. This survey gives some answers to the main question: "Has the firm made innovation during the five last years[8] considered period?". Each question corresponds to a particular definition of innovation and use a typology based upon two complementary criteria: the object of innovation and its nature. Finally we obtain several types that are, on the one hand, process innovation [called UT] versus product [UP] innovation versus "others" (that means organisational, commercial and packaging innovation) [UC], and, on the other hand, radical innovation [URAD] versus incremental innovation [UINC]. We test each case after we first considered the general case of innovation [U0].

Some words have to be said about the econometric structure of this model. We have first to come back to the theoretical model. When we speak about the determinant of innovation, we consider in fact the innovation propensity, a continuous variable whose value is comprised between 0 and 1. At the same time, the innovation measurement provided by the survey is a binary discrete one: Yes (there is innovation) or No. So we have to use a qualitative dependant variable model (Maddala, 1983): if y is the estimated variable (the innovation event), the model introduces the continuous "unobserved latent variable" y', with:

– $y = 1 \Leftrightarrow y' \geq y_0$
– $y = 0 \Leftrightarrow y' < y_0$

This latent variable can be built as the probability of innovation event:

– inno = 1 $\Leftrightarrow$ pinno $\geq y_0$,
with, for instance, $y_0 = 0.5$
– inno = 0 $\Leftrightarrow$ pinno $< y_0$

Thus we can understand that the latent variable is nothing but the innovation propensity. Even if the given data concern innovation and not its propensity, the technical constraint finally leads us to estimate a latent variable which is again the innovation propensity variable of the theoretical model.

At the end the general structure of the econometric model is:

$$\text{Ui} = \text{Logit}\,(L^*_{\text{firm}}, L^*_{\text{sector}}, X_{\text{firm}}, X_{\text{sector}})$$

Where L^*_{firm} represents the quality of labour factor employed by the firm, L^*_{sector} the quality of labour factor employed in the sector, X_{firm},the structural characteristics of the firm, X_{sector} the sectoral market structures.

The empirical field: a small firms world

We choose the case of French Food Industries to test our model, because of two reasons. The first is the weight of these sectors in terms of employment: more than 500 000 people are concerned. Diversity among these sectors is a second source of interest: 41 different sectors compose that field, with very various characteristics in terms of processes, products, firms or market structure. So, the results issued from the study of these sectors can be generalised to a larger field, as, for instance, the whole French industry. At the opposite, our empirical knowledge allows us to assume that these industrial sectors are not "high-tech" ones, or representative of more advanced sectors,[9] in terms of innovation. Thus, that research will permit us to sum up major trends, and certainly not to identify some avant-garde tendencies.

A very strong characteristic of our empirical field is the relative weight of small firms. If we first consider the Table I, we can notice the importance of small firms in terms of employment: half of our sample is composed of very small firms (less than 50 employees),[10] and only 5% are firms that employ more than 500 salaries.

TABLE I
Basic statistics: average values by size

Size (Number of employees)	10–49	50–99	100–199	200–499	≥ 500
K/L (KF)	303.3	379.3	398.3	480.2	488.4
X237 (%)	4.57	3.55	2.74	3.22	3.78
X38	1.60	2.03	2.02	1.86	2.40
X382	0.29	0.33	0.77	0.95	1.36
X46	4.40	4.13	4.38	4.32	4.97
X47	0.73	1.23	1.56	1.86	2.42
X48	3.21	4.17	4.62	4.81	5.26
X61	43.4	41.4	39.8	42.4	40.4
U0 (freq.)	63	71	82	84	95
URAD	24	31	43	54	76
UINC	57	66	78	82	94
UT	34	49	61	78	86
UP	54	61	74	76	88
UC	36	44	60	62	78

So, it clearly appears that we have to study a population mostly made up of small firms. The basic statistics of Table I also shows that the job structure depends on size: small firms employ a less part of engineers, R&D personnel and intermediate categories. The value of manager part first decreases according to the size, then increases. This has to be analysed in regard to the specific role of small firms managers. In very small firms, the relative weight of manager is heavy but its function is not so specialised and its tasks are more various than those from management staff in big firms.

III. Our results

Two models will be successively estimated. We first use a reduced one, focussing on the labour factor dimension, then will be estimated the general model including all the explanatory variables.

III.1. *The labour factor effect*

This simplified version of our model only includes the level of employment and the quality of the labour factor employed in the firm as explanatory dimension, and can be written as:

INNO = Logit[11] (C, X237, X38, X382, X46, X47, X48, X61, LL)

The results are presented in Table II. The model, even in its reduced form, seems to be robust, since a significant part of the studied phenomenon can be explained by the use of labour factor as single explanatory dimension. However the firm size variable LL has the strongest positive effect on innovation, whilst quality of labour factor plays a complementary role that depends on the kind of innovation that is considered.

Size of the firm: the major effect

The innovation propensity of the firm is mainly determined by its size: the bigger is the firm, the more it innovates. We even made a complementary estimation, based on the use of dummy variables T_i ($i = 0$ to 4) that indicates the size class of the firm. Figure 1 clearly points out the existence of a strong, and increasing relation between the size and the innovation propensity, without any appearing threshold.

Thus we are comforted in our previous assumption of a log-linear relation between the firm innovation propensity and its size.

Labour factor quality: an influence that depends on the kind of innovation

Labour factor quality plays an important role but one that deeply differs in accordance to the kind of innovation and to the job category.

We can first identify some job categories that do not seem to play any role in the innovation process: the "Managers" [X237], the "administrative and sales intermediate categories" [X46], the "foremen" [X48], all corresponding to hierarchical and decisional function, stated at different skill levels. At the opposite, one category, the "Engineers" [X38] play an important role whatever kind of innovation is considered.

At the same time, the influence of "R&D personnel" [X382] is most important in the case of radical innovation, especially product innovations, while the "Technicians" category [X47] appears to play an important role in the case of incremental innovations, particularly process innovations.

We can propose an explanatory scheme. Its first foundation concerns the prevalence of the technical functions versus the hierarchical or management ones. Obviously innovation is still considered as a technical phenomenon where management does not play the biggest role. The non-technical functions do not act significantly upon the process, with only one exception that concerns the organisational or commercial type of innova-

TABLE II
The influence of labour factor quality on the innovation propensity

Inno	fréq	Ftest	CSTE	X237	X38	X382	X46	X47	X48	X61	LL
U0	71.2	*** 103.9	*** –1.27 (12.31)	ns	4.34 (2.90)	6.35 (1.47)	ns	ns	ns	** –0.87 (10.11)	*** 0.58 (54.81)
UP	62.3	*** 84.4	*** –1.47 (21.14)	1.79 (1.57)	2.46 (1.11)	4.97 (1.22)	ns	ns	ns	* –0.46 (3.29)	*** 0.49 (54.00)
UT	47.3	*** 151.8	*** –2.84 (81.95)	ns	2.93 (1.59)	ns	ns	** 5.68 (6.48)	ns	ns	*** 0.64 (97.11)
URAD	33.4	*** 123.9	*** –3.06 (97.23)	ns	*4.61 (3.56)	** 8.57 (4.35)	ns	ns	–1.89 (1.71)	–0.35 (1.61)	*** 0.56 (85.30)
UINC	66.1	*** 112.6	*** –1.87 (29.30)	1.51 (1.06)	3.27 (1.84)	4.72 (1.00)	ns	3.11 (1.63)	ns	–0.41 (2.49)	*** 0.62 (69.82)
UC	45.3	*** 100.4	*** –1.99 (45.44)	ns	3.21 (1.95)	ns	–0.72 (1.10)	–2.39 (1.15)	ns	*** 0.73 (8.33)	*** 0.51 (71.60)

*, **, ***: The coefficient is significant at the 0.1, 0.05, 0.01 levels.
The Wald test result is between brackets under the associated coefficient.
ns: the Wald test value is lower than 1.

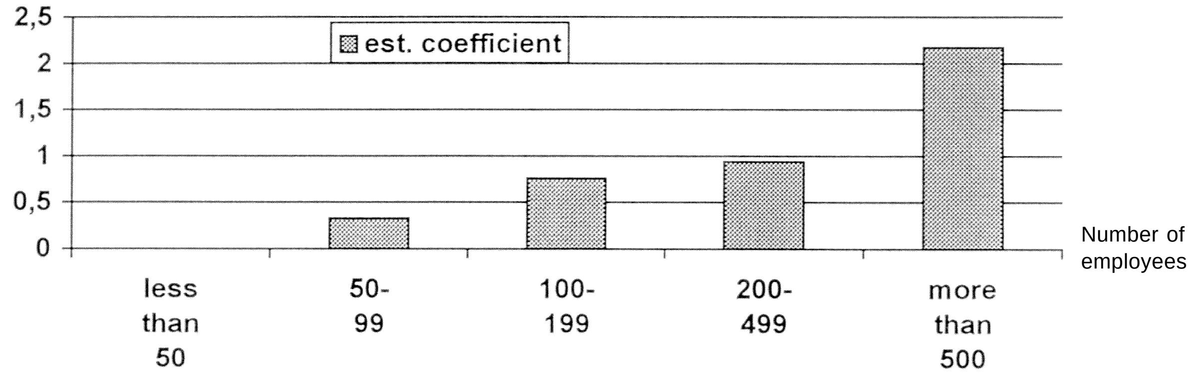


Fig. 1. Size and innovation: the estimated value of the LL coefficient in the innovation propensity model.

tion. In that particular case, we can say that these non-technical categories play a (limited) role, based upon their specific know-how, which must not be mistaken for a kind of supervision or management of the whole innovation process. We can also add that this first result is true whatever skill level is considered: upper or intermediate. So, we can conclude that the functional dimension is not redundant in our labour factor quality definition.

"Engineers" play a role in about every case of innovation, but it is rarely the first role. Their function seem to be a technical managing and supervision in the product innovation case where conception is devoted to R&D personnel, whilst in the process case, engineers are concerned with conception of innovation and technicians are involved in the implementation phase.

A more precise lecture of our Table II results emphasises two opposite forms of innovation: radical product innovation versus incremental process innovation. In the first case, the "R&D" employees play the biggest role, whilst "technicians" are in this situation in the second case. The engineers always step in the process but never as the main actors. Thus, the skill level of job categories clearly matters in this opposition: a kind of innovation is clearly connected to scientific and formal knowledge whilst an another involves other capabilities, some kinds of know-how more integrated to the firm concrete activity. This opposition between R&D knowledge and technical know-how reflects the influence of the different phases of innovation process, as we stated in part I. In the case of radical innovation, the conception phase is the most important, whilst implementation phase matters more in incremental innovation.

However we should not go too far in that way, especially by using the know-how argument. If we consider now the "skilled workers", we obtain systematically negative and significant coefficients. "Learning by doing" does not seem to produce any effect at the skilled workers level. How to explain that? By considering that, in that case, function is more important than know-how. The skilled workers must be considered as workers assigned to direct production which is a function where innovation is not a natural goal. So, even if they potentially own some specific knowledge, their functional assignment prevents them to summon up that capability in the innovation process. Another explanation is proposed by Bartel and Lichtenberg (1987), that introduce a temporal dimension. The adaptation delay to innovation would be longer in the case of employees whose capabilities are more based on seniority and accumulated know-how.

Type of innovation	Radical	Incremental
Product	1: R&D personnel (conception) 2: Engineers (implementation)	1: Engineers (implementation) 2: R&D Personnel (conception)
Process	1: Engineers (conception) 2: Technicians (implementation)	1: Technicians (implementation) 2: Engineers (conception)

Fig. 2. Types of innovation: the main influent job categories.

III.2. *A comparison of the different explanatory dimensions*

We hence estimate the general form, including all the explanatory dimensions:

$$\text{pinno} = f(L^*_{\text{firm}},^{12}\ L^*_{\text{sector}},\ X_{\text{firm}},\ X_{\text{sector}})$$

or, more precisely:

$$\text{inno} = \text{Logit}\ (C, X382, X47, X61, LL, LKL, FJ, RDS, C4, LCAS, Si^{13})$$

The results are presented in Table III.

The major role for firm variables
The results clearly indicate that the firm variables (X_{firm}) play the main role. Without any surprise, the size of the firm is the strongest positive determinant of the innovation propensity, while capital-intensity contribution concerns only certain kinds as process innovations. Legal status has an influence since co-operative societies are less often innovative than private firms, even after controlling the sectoral effect. Co-operative firms in food industry have to deal with specific constraints due to their relation with farmers and this can be an explanation for the lack of innovation. The results of the previous estimation are confirmed in the case of the firm labour factor quality: a strong positive effect of “R&D personnel” and “Technicians”, a negative effect of the “Skilled workers” category. However, this influence is less strong than the firm size effect.

Sectoral variables: spillover and sectoral belonging effects
If we now consider the sectoral variable, the part of “R&D personnel” in the sectoral employment has a clearly positive influence on the firm innovation propensity. This could lead us to assume the existence of R&D spill-over. When the potential innovation capability is high in a sector, it seems plausible to think that each firm can take at least partially advantage of it. In the case of our sectoral market structures the innovation propensity is negatively correlated with the concentration degree as well as with the size of the market. Anyway the best situation for innovation seems to be a large firm located in a not highly concentrated market.

The discriminating role of the sectoral variable provides us with some specific information about innovation in food industry: the dairy industry (36) and the canning industry (37) firms are significantly more innovative than the sectoral average while the beverage industries (41) are less so. Without going too far in this analysis of the particular case of French food industry, we can at least emphasise the effect of the characteristics of products and equipment, approximated through the use of sectoral dummies. The existence of some technical barriers to innovation, as for instance the nature of the intermediate animal products in catering, can partly explain these differences.

IV. Conclusions

The importance of labour factor quality
A first lesson drawn from this work is the importance of labour factor quality, as we defined it. Firstly, this added explanatory dimension is a significant one and contributes to explain by itself a part of the observed interfirm differences. Secondly, it greatly helps us to understand and to qualify the influence of other variables. In a theoretical dimension, it validates our multistep innovation scheme. Each phase of innovation does not imply the same job categories, and each kind of innovation does not confer the same importance to the different phases. In that sense, labour factor quality can be considered as a tool to discriminate the different kinds of innovation.

More information about the nature of innovation
We can extract of all this some precious information about the real nature of innovation. First, the interest of the product/process distinction and, furthermore, of the radical/incremental distinction is proven. Moreover, to speak about “innovation”, taken as a whole, does not make sense, since the tests with the U0 variable, which corresponds to that general definition, do not lead to any significant result. On the opposite, the analysis of radical innovation gives the strongest results. Less variables play a role but each role is more marked. The highest positive coefficients, associated to R&D variables (internal personnel as well as sectoral ones) clearly indicate that the R&D influence mostly concerns this kind of innovation, whether it is the result of diffusion or of direct

TABLE III
The innovation propensity determinants

Inno	fréq	Ftest	X382	X47	X61	LL	LKL	FJ	RDS	C4	LCAS	S36	S37	S38	S39	S40	S41
U0	71.2	*** 393	ns	ns	** –0.68	*** 0.56	*** 0.28	*** 0.61	** 0.26	** –0.02	***–0.37	** 0.85	*** 0.78	ns	ns	* 0.66	ns
					(5.61)	(49.75)	(13.49)	(7.23)	(4.53)	(4.63)	(16.34)	(6.24)	(9.06)			(3.34)	
UP	62.3	*** 215	ns	ns	* –0.47	*** 0.49	** 0.16	** 0.45	** 0.21	* –0.01	** –0.29	*** 0.85	*** 0.66	ns	0.28	ns	** –0.63
					(3.10)	(51.04)	(4.90)	(4.48)	(3.91)	(2.79)	(11.75)	(7.39)	(8.16)		(1.66)		(3.99)
UT	47.3	*** 195	ns	* 4.20	ns	*** 0.61	*** 0.36	ns	*** 0.28	–0.01	***–0.36	0.32	* 0.37	–0.22	–0.25	ns	** –0.75
				(3.23)		(87.27)	(21.94)		(7.48)	(1.73)	(18.63)	(1.15)	(2.91)	(1.07)	(1.43)		(5.61)
URAD	33.4	*** 319	6.19	ns	ns	*** 0.56	0.12	*** 0.72	*** 0.42	ns	***–0.29	0.35	** 0.52	ns	ns	–0.43	* –0.60
			(2.15)			(77.46)	(2.09)	(9.87)	(15.80)		(10.15)	(1.25)	(5.55)			(1.63)	(3.29)
UINC	66.1	*** 298	ns	ns	–0.40	*** 0.59	*** 0.30	** 0.44	*** 0.32	** –0.02	***–0.36	** 0.77	**0.65	ns	ns	ns	* –0.54
					(2.10)	(62.47)	(16.33)	(3.93)	(8.04)	(5.23)	(17.44)	(5.58)	(7.23)				(2.77)
UC	45.3	*** 126	ns	ns	* –0.45	*** 0.48	0.08	** 0.46	ns	0.01	***–0.29	0.34	* 0.35	** –0.56	–0.25	ns	ns
					(2.98)	(61.05)	(1.21)	(5.39)		(1.71)	(11.55)	(1.33)	(2.81)	(6.77)	(1.40)		

*, **, ***: The coefficient is significant at the 0.1, 0.05, 0.01 levels.
The Wald test result is between brackets under the associated coefficient.
ns: the Wald test value is lower than 1.
Sectoral dumies Si: Dairy (S36), Canning (S37), Bakeries (S38), Grain (S39), Beverages (S41), others (S40).

conception inside the firm. In radical innovation people whose function and academic skill level naturally appoint for this exert the greatest influence. The "Learning by Doing" effect mostly concerns the incremental innovation and particularly process innovation. However this Learning by Doing has to be accompanied by a certain level of formal scientific knowledge: technicians are concerned but not skilled workers and, anyway, engineers are always accompanying the innovation process.

That stylised fact can be related to the distribution of innovation among firms. The first radical form mostly concerns large firms that can employ people owning some scientific knowledge whilst small firm have to use some more specific know-how.[14] The following figures show how the type of innovation is related to firm size.

That result helps us to understand the nature of the relation between innovation and firm size in some industrial sectors. First, we can say that the positive relation is a partial one that concerns radical innovation. Secondly, we can assume that in this case, this is due to a job structure phenomenon: small firms are less innovative in the radical sense because they do not own the specific competencies needed for that specific kind of innovation.

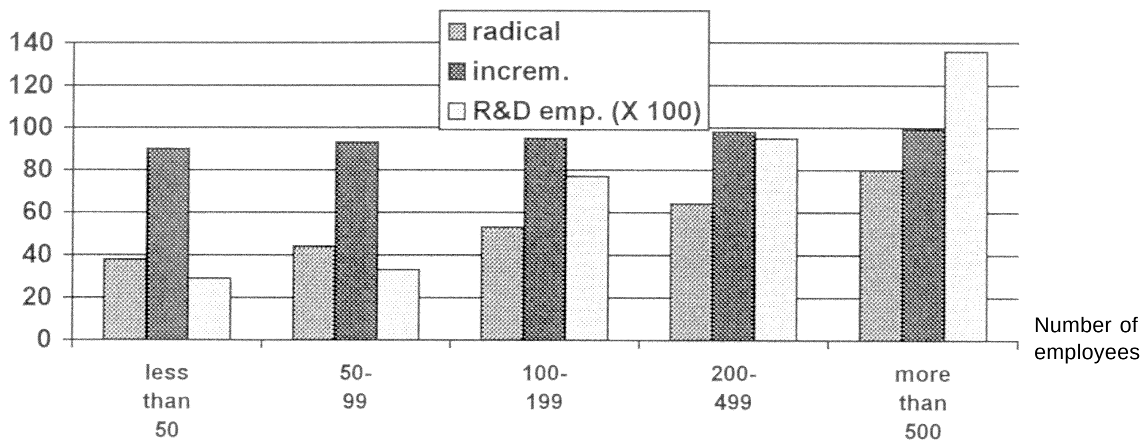
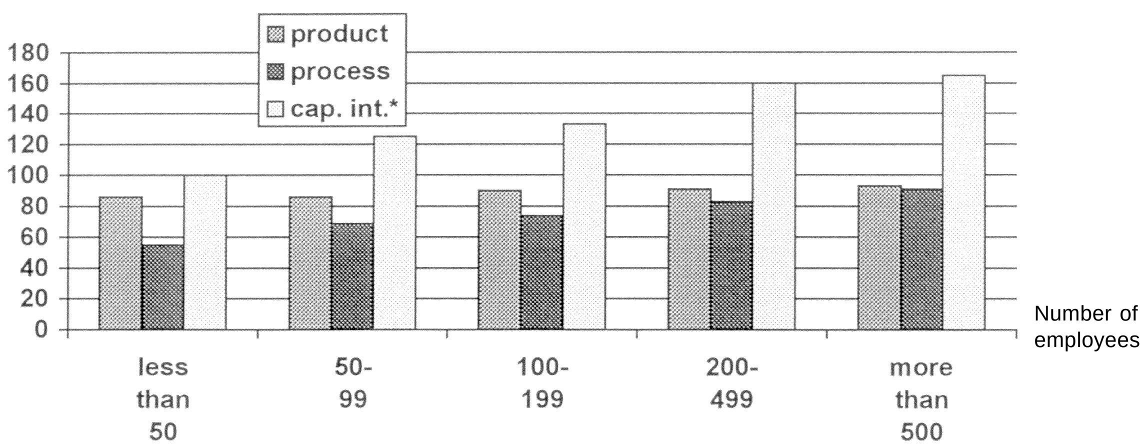


Fig. 3. Type of innovation (in % of the innovating firms), part of R&D and firm size.



* 100 = "less than 50 employees" value for capital intensity.

Fig. 4. Type of innovation (in % of innovative firms), capital intensity and firm size.

If we consider now the distinction in terms of innovation object, a different analysis can be made. Small firms are less innovative in the case of process innovation, not in the product innovation case. However in that topic, job structure does not play the first role that is devoted to capital intensity: large firms implement more often process innovations because they are involved in more capital-intensive activities where scale effects are important.

These two dimensions, job structure in the case of radical innovation and equipment scale effects in the case of process innovation, finally explain and qualify the real nature of the relation between innovation and firm size.

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Appendix

Data

The data that are used are individual firm data. Our cross-sectional sample of 1493 firms concerns the year 1990 and comes from of three merged French statistical sources:

* The "ITI (Innovation Technologique dans l'Industrie)" conducted by the French Ministry of Industry provides us a direct measurement of innovation.
* The "Enquête Annuelle d'Entreprise", conducted by the "Service des Etudes et de la Statistique du Ministère de l'Agriculture (SCEES)" provide us some indicators related to the firm structure:

– LKL, the capital intensity in its logarithmic form;
– Si is a set of dummies for the sectoral belonging;
– FJ, that represents the legal status of the firm (co-operative/private);

and to the sectoral market structure:

– C4: for the sectoral concentration (which means the part of the four greatest firms in the whole sector sales);
– LCAS: for the market size (which means the sectoral sales, under its logarithmic expression).

* The "Enquête Structure des Emplois", conducted by the INSEE and the French Ministry of Labour, provides data about the employment level and the job structure. We used it to define LL, which means the firm number of employees (under its logarithmic expression) and L*, the quality of labour factor, with the following variable:

– X237: the part of "managers" in the total employment;
– X38: the part of "engineers";
– X382: the part of "R&D personnel";
– X46: the part of "Administrative and sales intermediate categories";
– X47: the part of "Technicians";
– X48: the part of "Hierarchical intermediate categories" (as foremen);
– X61: the part of "Skilled workers".

By this, we assume that the other job categories, "office workers" and "unskilled workers" are not involved in the innovation process.[15]

Notes

1 Some of these points come from the lecture of the Audretsch's survey (1995).
2 For an interesting example of this approach, see Bahk and Gort (1993), that use the size of the firm as a proxy for seniority and the corresponding accumulated knowledge.
3 For instance, we can imagine that whilst scale effects would permit to large firms to use some new process issued from R&D, the existence of some bureaucratic organization would prevent it to benefit from innovation issued from know-how.
4 See for instance Jaffe (1986), or Krugman (1991).
5 This is also the occasion to build a link with sociological works as those of Mintzberg (1982).
6 The data used and the list of variables are reported in the Appendix.
7 See for instance Griliches (1990, 1994) or Mairesse and Mohnen (1990).
8 The period was 1985 to 1990, whilst the survey has been conducted at the end of 1990.
9 At the opposite of biotechnology industries (that are not classified in that food industry group), for instance.
10 One can notice that the firms that employ less than 10 salariées are not included in the survey we used. It seems a good thing to us, because the general specification of our model is not adapted to the very small firms case. Particularly

the labour factor quality is difficult to measure because the general job classification does not reflect the characteristics of very small firm job structure.

[11] We use a Logit model: $y_i = bX_i + u_i$. The distribution of the error u_i is a logistic one, and we use the Maximum of Likelihood estimator (Maddala, 1983).

[12] In this specification, we only present the job categories coefficients that are significative, for some presentation reasons.

[13] The "Si" are sectoral dummies and we use the Meat Industry (35) as the reference situation.

[14] Of course, this is true in the case of industry classical sectors, the results would be obvously different if we should have studied biotechnological firms, for instance.

[15] We have also to recall that the non introduction of at least one of this category inside the estimated form is an econometrically necessary condition to avoid the strict colinearity between variables which would result from:

$\Sigma_{f=1}^{F} \Sigma_{s=1}^{S} L_{fs}/\mathrm{L} = 1$.

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