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Labour market competition & innovation : Evidence from Defence-related firms

draft

Abstract:

This paper deals with the recruitment of highly skilled workforce in a "patent race" framework. The model applies to French Defence-related firms. It has to take two specific features into account: the oligopsonistic nature of the market for sector-specific skills because of their transferable character (Stevens 1994) and the crucial role of technological leadership in competition (Harris & Vickers 1985). Considering both the uncertainty on the benefits of R&D efforts and the complementarity between skills and new technology, we model a duopsonistic labour market. A bivariate probit on French data shows a positive relationship between innovative ability and the ease of further highly skilled recruitment, but this pattern is not specific to Defence-related firms.

Theme: Labour demand

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1. Introduction

The innovative ability is a crucial element of success for a Defence-related firm. A technologically updated equipment is a necessary condition for an army to fulfil its task. So the government has to make sure that the organisation of the national research effort and the management of strategic skills will maintain and enhance the technological leadership of its industry. Firms capabilities to innovate are for a large part due to the skills of their workforce. Our research program is concentrated on this human part of these industrial skills. We want to evaluate the impact of an innovative context on the highly skilled recruitment. Our analysis is based on two starting points. On the one hand, papers of labour economists dealing with human capital in an imperfect framework. On the other hand, the literature on "patent race" which models the possibility of an exclusive innovation.

There is two interconnected races, the first for innovation, the second for human capital. “Patent race” models have been developed in industrial organisation to take into consideration the research policies of “high tech” firms (Dasgupta & Stiglitz 1980, Ulph & Ulph 1994). The main hypothesis in this framework is that only one firm can implement the innovation. A patent, or a similar mechanism, prevents other competitors from doing the same. The main condition in order to develop innovations seems the availability of human capital (Roth & Xing 1994), therefore recruiting new competencies will be a strategic element of future innovative ability. In some industrial sectors, the speed of technical progress is continuously increasing, that's why the need for flexible and highly qualified workforce becomes more and more important. The main hypothesis of this model is that recruitment will be influenced by the innovative context.

Defence-related firms give an original framework, highly relevant for this analysis. These markets are both technologic and oligopolistic, workforce qualifications are higher than the mean of the industry. Gibbs (2001) concludes that competencies needed by Defence-related firms have a Defence-specific character. Competition is based on innovation rather than price. In the French context, the army is now becoming an All Volunteer Force and military procurement budgets are shrinking. Industries are facing a double challenge: they have to maintain and enhance their technological advance by recruiting new competencies.

But they also face a lack of such highly qualified manpower in a context of growing needs due to technological competition.

Workforce human capital has, at least, two effects on firms situation. A direct one, higher individual human capital means higher individual productivity. But it is also a source of externalities in firms. For example, the liberty ships building during the world war II has shown a large learning by doing process (Rapping 1965). In this context, winning the loyalty of its manpower is a strategic proposition for these firms. For example, workforce reactions to poaching propositions are a crucial element in the building of a stock of human capital and of future success.

Modern tools of labour microeconomics (Stevens 1996, Acemoglu 1997, Acemoglu & Pischke 1999) allow us to take imperfect competition into consideration on the labour market as well as on the final product market. In this new framework, the dichotomy of Becker is enlarged. It allows skills to be of some interest for a small number of firms. This oligopsonistic situation will lead to strategic interactions among competitors. For example, the introduction of mobility costs will give to the incumbent employer a "monopsony power". This is an inciting for firms to invest in their manpower human capital, despite the poaching externality (Stevens 1996). This theoretical proposition is consistent with an important stylised fact of the European labour markets. Firms finance, at least in part, the training of their employees, even if these skills seem to be general. From the employer point of view, the acquisition of a stock of competencies is a necessary condition, but not a sufficient one, to innovate and to enhance the production process.

Another proposition which inspired this analysis is the idea of a complementarity between investment in new technologies and human capital. It has already inspired a huge literature since the seminal work of Griliches (1969) on the skill-biased technical change. Acemoglu (1997) has shown that this complementarity hypothesis can be responsible for multiple equilibria. The first where firms invest in new technologies and people invest in skills, the other where neither invest.

The theoretical model proposed here deals with the impact of firms' innovative capabilities on their recruitment of highly skilled manpower. We will evaluate effects of involvement in "innovation race" on labour demand. Afterwards, the main proposition of the model will be tested on a French database thanks to the “innovation” and “compétences pour innover” surveys. Firms will be identified as “defence-related” thanks to the French ministry of defence.

The second section presents the main contributions dealing with human capital in an imperfect framework or interested in the link between human capital and innovation. The third section develops the theoretical model and its main implications. The fourth section shows the building and the main statistics of the database. The fifth section presents the econometric test and the main results. The section six concludes.

2. Innovation and human resources strategic management: a survey of the literature

Many articles are dealing with the human capital analysis of skilled labour market and especially with the link between individual skills and firm innovation. Griliches (1969) has been the first to underline this relationship by distinguishing qualified and non-qualified labour. There is a global agreement on this complementarity among the empirical studies, following this seminal result. This hypothesis, highly intuitive, has been used in both micro and macro analysis in order to model the organisation of the labour market. We wouldn't be able to make an exhaustive presentation of the literature dealing with this subject. We will rather concentrate our attention on a few works close to our analysis both in their hypotheses and objectives.

Stevens (1994,1996) introduces a major change in the human capital analysis by labour economists. She breaks the Beckerian (1962,1964) dichotomy: on the one hand, there is perfectly general skills, which are equally useful for all firms. The labour market for such competencies is supposed to be perfectly competitive. On the other hand, there is purely specific skills which have an effect on the individual productivity only in the incumbent firm. In this case, the labour market is a monopsony and costs and benefits of on-the-job training have to be shared between employer and employee. Stevens introduces another alternative: "transferable skills" which are not a combination of general and specific skills. Such competencies are useful to a limited number of firms. The demand for such competencies will therefore be oligopsonistic. Gibbs (2001) defines “industry specific human capital for defense sector" to explain the results of the rate of return of skills for scientists and engineers of the American Department of Defense. Another hypothesis on competition imperfections is a necessary condition to model the strategic framework presented in the introduction.

In order to take strategic behaviour into account, it is necessary to model effects of monopsony power of employers on the labour market. It means that the employer can make a profit out of the transferable human capital of its manpower. For example, there could exist constraints on workers mobility after training. Stevens (1996) uses this hypothesis to develop a duopsony model, her objective is to explain why firms invest in apparently general training despite the poaching externality. The mobility of trainees is a crucial argument for the labour market equilibrium and the availability of transferable skills.

The existence of some stickiness in the inter-firm mobility of trainees explains that trained workers don't always choose the firm with highest wages. There are many possible explanations for this behaviour, but they are taken as exogenous in Stevens (1996). For example, a gratitude feeling for the incumbent firm or, at the opposite, an hostile atmosphere in teamwork could explain a psychological argument next to the wage differential in the matching decision. In Defence-related firms there's also constraining rules and contrats, people with strategic knowledge can't work for the competitor of his incumbent employer. The results obtained by Stevens in this framework are similar to those obtained by Acemoglu and Pischke (1998,1999). In these articles, the market power of employers comes from imperfect information.

Firm sponsored training depends on the "monopsony power" of employers. The more trainees are wage-sensitive, the less firms would be able to sponsor training. Because of the poaching externality, there will be under-investment in training despite the employer funding. This underlines the negative correlation between workers mobility and training observed in many empirical studies. But, we have to notice that if workers are perfectly wage-sensitive, employers have no monopsony power and can't subsidised on-the-job training. This corresponds to the Beckerian perfectly general training. The introduction of a specific element in the training program will constrain future mobility of trainees and then increase the employers inciting to sponsor training. Other papers take the complementarity between qualifications and new technologies into consideration to explain why firms fund apparently general training.

Acemoglu (1997) provides a theoretical analysis of skills acquisition in a context of costly job search. He obtains approximately the same results as Stevens (1996). The imperfect labour market induces constraint mobility after training. This context leads to firm sponsored training but at a suboptimally low level. Because of random quits, the future employer is unknown at the time of the training decision. This result comes from the inability to contract with future employers except the incumbent one. There is still a poaching externality problem.

The introduction of a possibility of innovation, supposed to be complement of individual skills, leads to multiple equilibria. Skills are supposed to be more valuable for workers if their employer innovate. And conversely, new technologies are more useful to firms if their manpower is more qualified. In this situation there is two opposite equilibria. On the one hand, all firms adopt the new technology and every workers increase their human capital. On the other hand, neither firms nor workers invest. The failure in co-ordination is due to imperfections on the labour market.

Acemoglu (1997b) in another paper adds the unemployment rate to this framework. If qualified workers run the same risk as non-qualified people to loose their job, which is a strong hypothesis, this would reduce their expected returns from training. This will induce less investment in training, so firms inciting to invest in new technologies are also reduced. These connections lead to a vicious circle and the probability of a co-ordination failure increases with the unemployment rate.

The strategic complementarity hypothesis is also a common hypothesis in the endogenous growth literature. For example, Redding (1996) analyses the impact of firms R&D spending and workers human capital investments on the growth rate of the economy. Many articles have been published on each of these arguments. In his paper, Redding is more interested in the relationship between R&D and human capital. This idea is based on empirical studies of Finegold & Soskice (1988) and Snower (1996) which show the possibility for an economy to be trapped in a “low skill” equilibrium, which induces low R&D efforts and then no need for highly skilled manpower. This seems to correspond to the case of Great Britain.

The preceding articles are interested in the acquisition of skills on-the-job, we are narrowing this analysis on the recruitment of skills previously acquired. The following model is based on the second step of Stevens (1996) model, “the labour market stage”. We will add to this theoretical framework, an innovation race whose results are still uncertain. Only one firm will be able to produce the new technology because the government propose only one procurement contract for each type of military equipment.

3. A recruitment race under pre-emptive innovation

In a matching model, Acemoglu (1997b), says that workers mobility is likely to discourage investments in new technologies by firms. But, in a context of innovation race, its anticipated result would also intervene in further capabilities for firms to recruit and retain workers. This is what we want to consider in this article. We are interested in strategic interactions due to both the sector-specific nature of skills and the results of the innovation race. It is worth noticing that the model which will be developed in the following strongly corresponds to the features of Defence-related sectors.

3.1. Hypothesis

The main hypothesis in this model is the introduction of imperfect competition on the skilled labour market, like in Stevens (1996). First, the demand for defence specific skills is oligopsonisitic, there will be strategic interactions between potential employers. Second, we suppose that there is some stickiness in workers mobility. The reasons why not all workers prefer to work for the firm with higher wages are taken as exogenous in this model. Explanations can be found in non-pecuniary tastes or contractual limits.

We don't take directly the innovation race into account, we concentrate our attention on its consequences on human resources management. Firms are more or less involved in the innovation race and the results of R&D spending are therefore uncertain. Many articles on "patent races" dealing with asymmetric competitors conclude that the "follower" can catch up the "leader" under some, more or less stringent, circumstances (see for example Fudenberg et alii 1983, Harris & Vickers 1985). As we are only interested in the recruitment process, we can take the expected results of the race as exogenous. We can summarise the range of results by a probability for each firm to introduce the innovation, *id est* to win the innovation race thanks to previous individual features.

Consider a sector of the economy in which there is only two firms (*A* & *B*) competing on the same final product market. We suppose they have sector-specific needs in terms of competencies. Or, leading to the same formulation, they are located on a separate market apart from the rest of the whole economy in which general skills are *de facto* transferable. To the duopoly on the final good market corresponds a duopsony on the skilled labour market. We consider perfectly transferable skills. It means that they are equally useful in both firms, but of no interest in the others. This is particularly true for defence-specific skills which are innovation-oriented. The number of workers which have these competencies is fixed (*H*). In this paper, we don't ask ourselves how they acquired it. As in the first step of Stevens' paper (1996), we analyse only the recruitment process. As the labour supply is given, the strategic variables are wages (w_A & w_B).

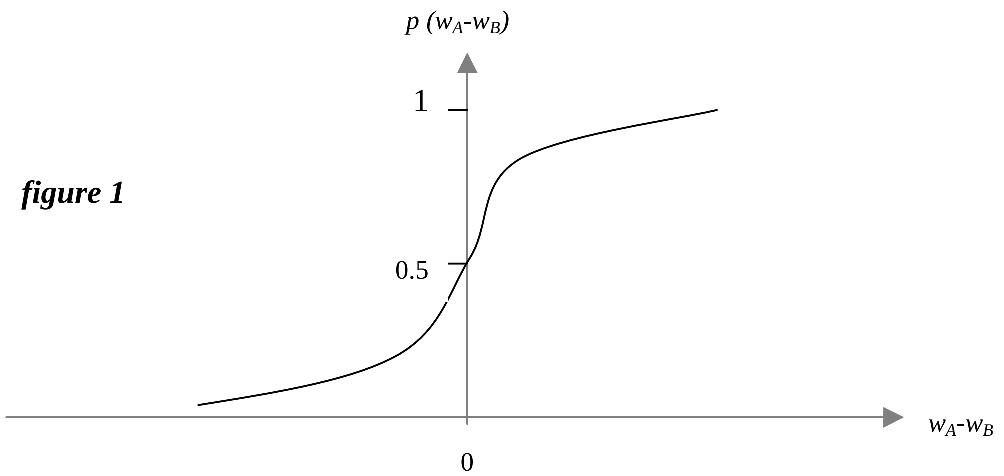
It is also necessary to model imperfect mobility. Although workers can be poached in their incumbent firm, they don't choose necessarily to go to the firm with higher wages. The wage differential is not the only argument of the future employer choice. The overall repartition of the skilled manpower between employers can be sum up by a function of the wage differential. If wages are w_A & w_B, the probability for each skilled worker to work in firm A is $p(w_A-w_B)$. This probability is increasing in the difference in wages. The complement $(1-p(w_A-w_B))$ is of course the probability of working for B. This function $p(.)$ is simply a distribution function symmetric in zero and its slope illustrates the sensitivity to wages. The general features of $p(.)$ are:

$$p(0) = 0.5 \; ; \qquad p(w_B-w_A) = 1-p(w_A-w_B) \; ;$$

$$\forall\, w_A-w_B > 0 \qquad p'(w_A-w_B)>0 \; ; \qquad p''(w_A-w_B)\leq 0$$

The general profile of this function is illustrated by figure 1:

figure 1



In order to take the innovation race into consideration, we introduce an exogenous probability for each firm to implement the innovation. If participation constraints are respected for both firms, we suppose that firm A will innovate with probability ψ and its competitor B with the complement $(1-\psi)$. The costs due to the innovation race (i.e. R&D spending) are fixed and irrecoverable as in Aghion & Howitt (1994). We rely on the production function defined by Redding (1996) in a macroeconomic framework. The production technology is represented by a parameter k which is a multiplier of the number of skilled workers. This definition represents in a simple way the complementarity between competencies and technology. The winner of the race implements a new technology corresponding to a parameter k_H and the other competitor keeps the old one k_L ($k_L<k_H$). This technological gap will play a major role in the decision to get involved or not in the race. Firms are supposed to be risk-neutral and their objective is to maximise their expected profit. Because of sunk costs and of uncertainty on the results of the race, there exists a threshold on the number of employees to make the involvement in the race profitable in expectations. It is defined in relation with the innovation parameters ψ, k_H & k_L.

The following model is based on the framework of "the labour market stage" of Stevens (1996), duopsony and imperfect mobility. Our contribution is the introduction of an exclusive innovation which can induce asymmetry in the labour productivity (ψ, k_H & k_L).

3.2. Duopsony equilibrium

The production function of firm A is defined as:

$$y_A=k_A.H.p(w_A-w_B)$$

where $k_A \in \{k_l\ ;\ k_h\}$ is the technological parameter of firm A, H the number of qualified workers and $p(w_A-w_B)$ the share of this manpower which will work for firm A. And, for B:

$$y_B=k_B.H.(1-p(w_A-w_B))$$

The expected profits of each firm are therefore :

$$E\,[\Pi_A\,(w_A, w_B)] = E(y_A) - w_A\, H\, p(w_A-w_B) - c \qquad (1)$$

$$\Leftrightarrow\ E\,[\Pi_A\,(w_A, w_B)] = [\psi k_h + (1-\psi)k_l - w_A]\, H\, p(w_A-w_B) - c \qquad (1')$$

and

$$E\,[\Pi_B\,(w_A, w_B)] = E(y_B) - w_B\, H\,[1 - p(w_A-w_B)] - c \qquad (2)$$

$$\Leftrightarrow\ E\,[\Pi_B\,(w_A, w_B)] = [\psi k_l + (1-\psi)k_h - w_B]\, H\,[1 - p(w_A-w_B)] - c \qquad (2')$$

Because of the sunk costs of research and development, there exists participation constraints to the innovation race. A firm will invest in R&D if, and only if, profit expectations are higher than the profit obtained without participating to the race. These conditions are defined as follows: for firm A,

$$(k_l\text{-}w_A)\ H\ p(w_A\text{-}w_B) < [\psi k_h + (1\text{-}\psi)k_l - w_A]\ H\ p(w_A\text{-}w_B) - c$$

$$\Leftrightarrow H\ p(w_A\text{-}w_B) > c/\psi\,(k_h\text{-}k_l) \qquad \text{(C1)}$$

and for firm B,

$$(1\text{-}w_B)\ H\ [1\text{-}p(w_A\text{-}w_B)] < [(1\text{-}\psi)k_h + \psi k_l - w_B]\ H\ [1\text{-}p(w_A\text{-}w_B)] - c$$

$$\Leftrightarrow H\ [1\text{-}p(w_A\text{-}w_B)] > c/(1\text{-}\psi)\ (k_h\text{-}k_l) \qquad \text{(C2)}$$

The wage determination for both firms comes from the expected profit maximisation. Depending on the respect or not of each constraint, the objective functions will be written differently.

- If C1 and C2 are not verified, it isn't worth for both firm to engage in the race. The labour productivity is k_l for both firms. It's the case developped by Stevens (1996).
- If the constraint is verified for only one firm. It would innovate with certainty. Then ψ equals 0 or 1 depending on the leader.
- It's only when both constraints are verified that the race takes place and uncertainty occurs. It happens when innovative capabilities are close to each other.

In this last situation, and supposing that agents are risk neutral, we can calculate the following expected wages.

$$\frac{\partial E(\Pi_A)}{\partial w_A} = -p(w_A - w_B) + [\psi k_h + (1-\psi)k_l - w_A]p'(w_A - w_B) = 0 \quad (3)$$

$$\Leftrightarrow \quad E(w_A) = \psi k_h + (1 - \psi)k_l - \frac{p(w_A - w_B)}{p'(w_A - w_B)} \qquad (3')$$

and

$$\frac{\partial E(\Pi_B)}{\partial w_B} = -[1 - p(w_A - w_B)] + [\psi k_l + (1-\psi)k_h - w_B]p'(w_A - w_B) = 0 \quad (4)$$

$$\Leftrightarrow \quad E(w_B) = \psi k_l + (1\text{-}\psi)k_h - \frac{1 - p(w_A - w_B)}{p'(w_A - w_B)} \qquad (4')$$

(3') and (4') correspond to wage determination rules of both competitors. They are defined as the expected marginal productivity of skilled workers less a ratio, which is called by Stevens the "monopsony power" of the firm. It corresponds to a rent captured by the employer. It depends on both difference in wages and constrained mobility profile. The duopsony equilibrium is defined by the respect for both wage equations. It is possible to sum up the equilibrium in a single equation:

$$E(w_A\text{-}w_B) = [\psi k_h + (1\text{-}\psi)k_l] - [\psi k_l + (1\text{-}\psi)k_h] + \frac{1-2p(w_A-w_B)}{p'(w_A-w_B)} \qquad (5)$$

The main features of the equilibrium can be derived from a systematic study of wages proposed by each firm. The equilibrium is also sensitive to innovation parameters. It is an interesting question to analyse this sensitivity. And finally, we will also discuss participation constraints to the innovation race. Our first conclusion is that our formulation keeps the Stevens results i.e. when firms are symmetric (here when $\psi=0.5$), expected productivities are equal and wages are also identical. Stevens result is a special case of our model. The distinction of this article is the possibility for competitors to have different technology levels.

3.3. results and comments

Throughout this paragraph, we will assume that firm A has better innovative capabilities than B. It means that probability for firm A to win the innovation race is higher than the one of B. In the model, it corresponds to $\psi>0.5$. **All the results presented further for A will apply to B if $\psi<0.5$ because leader and follower roles are symmetric**. Perfect identity between the competitors seems to be a pathologic case. Because of the number of variables not mentioned here (history, R&D organisation), asymmetry between firms seems too be the casual case. So we suppose in the following that:

$$\psi > 0.5 \ \&\ k_h > k_l$$

Under these hypothesis, the expected productivity in firm A ($\psi k_h+(1\text{-}\psi)k_l$) is strictly higher than the one of B ($(1\text{-}\psi)k_h+\psi k_l$). In order to determine the equilibrium, we can distinguish three exclusive alternatives.

First case: $w_A=w_B$

The left hand side and the third term of the right hand side of equation 5 are both equal to zero. But the difference between productivity terms is strictly positive with respect to the hypothesis presented above. Equal wages are not a solution for equation (5). So, exclusive innovation and especially asymmetric probabilities to implement it, question the symmetric equilibrium of the duopsony obtained by Stevens (1996).

Second case: $w_A<w_B$

The left hand side of equation (5) is strictly negative. But at the same time the right hand side is strictly positive. The results are inconsistent with the equilibrium. It is therefore impossible for firm B to have more employees than firm A at the equilibrium.

Third case: $w_A>w_B$

In this case, firm A will have a higher probability than B of recruiting highly skilled workforce. This is the solution set of equation (5) if, and only if:

$$[\psi k_h + (1-\psi)k_l] - [\psi k_l + (1-\psi)k_h] > \frac{1-2p(w_A-w_B)}{p'(w_A-w_B)}$$

$$\Leftrightarrow [\psi k_h + (1-\psi)k_l] - \frac{p(w_A-w_B)}{p'(w_A-w_B)} > [\psi k_l + (1-\psi)k_h] - \frac{1-p(w_A-w_B)}{p'(w_A-w_B)}$$

This corresponds exactly to $w_A>w_B$, so there is no additional constraint, the solution set of equation (5) is therefore simply defined by $w_A>w_B$, the analytical result depending on the distribution of $p(w_A-w_B)$.

From the solution set, the monopsony power is higher for the leader. It corresponds to an higher rent on each employee. The gap between marginal productivity and monopsony power is wider in firm A. But expected wages are also higher. This result shows that expected benefits from an higher probability to innovate are shared between employer and employees. The innovation parameters (technological gap k_h-k_l and innovative capabilities ψ) play therefore a crucial role on the equilibrium of the labour market by defining the asymmetry between firms. It is necessary to investigate further the impact of these parameters. First, we have to discuss participation constraints under the hypothesis of this paragraph.

Thanks to the results obtained, we can conclude that if the constraint is respected for the follower, it will necessary be the case for the leader.

$$w_A>w_B \Rightarrow H\,p(w_A-w_B) > H\,[1-p(w_A-w_B)]$$

$$\psi > 0.5\ \&\ k_h > k_l \quad \Rightarrow \quad c/(1-\psi)\,(k_h-k_l) > c/\psi\,(k_h-k_l)$$

$$\text{if} \quad H\,[1-p(w_A-w_B)] > c/(1-\psi)\,(k_h-k_l) \qquad \text{(C2)}$$

$$\text{then} \quad H\,p(w_A-w_B) > c/\psi\,(k_h-k_l) \qquad \text{(C1)}$$

It is important to notice that this result is not reversible. It is possible, and quite intuitive, that only A, *i.e.* the leader, will have enough incentives to invest in R&D and to get involved in the race. In this case, ψ becomes equal to one and there is no more strategic interactions. The gap between both competitors is then maximum and the results obtained in the following will apply. The decision of acquiring the new technology is a strictly internal decision. If we try to make comparative static on the two thresholds, sunk costs and technological gap have the same impact on both thresholds: higher costs or lower gap lead to an higher threshold on the number of skilled employees in order to engage in the innovation race for both firms. On the contrary, the impact of the exogenous probability is not the same for the two competitors. An higher probability for A to implement the innovation leads to higher expected profits and a lower number of employees to make the participation in the race profitable. But, this will have the opposite effect for firm B.

Given everything else fixed, there exists a threshold on ψ above which only firm A has enough incentives to spend money on R&D. In such a situation, there is no more race. All these discussions are allusive on the determinants of the innovation process, but they are consistent with the results obtained by many articles dealing with the problem of patent races. For example, Harris and Vickers (1985) conclude that the race takes place if, and only if, the initial "distance" between competitors is not too large. In our model it corresponds to not too divergent exogenous probabilities of implementing innovation. The following results are based upon the hypothesis of both constraints verified.

The impact of innovation parameters leads to the same results for expected profits and remuneration. If the technological gap is growing, then it enhances expected profits for both firms, and *ceteris paribus*, it allows higher wage expectations for workers. But, on the contrary, an increase of ψ leads to a divergence of the profits expectations. If parameters variations are included in the range where innovation race takes place, wages follow the same evolution than profits.

Another important point to be discussed is the profile of workers constrained mobility. We choose in this presentation to work with a very general function, but some specific features have to be mentioned. The *p*-function and its first derivative define the monopsony power, *i.e.* the rent, for each firm. If p converges rapidly on one for $w_A > w_B$, it means that skilled workers are highly wage sensitive. It induces low monopsony power for both firms. Contrary to Stevens results, the equilibrium of the model presented above leads to different wages. So the equilibrium is much more sensitive to the profile of the *p*-function.

The duopsony equilibrium presented above underlines the positive relationship between participation, or anticipated success, in the innovation race and skilled workforce recruitment capabilities. This analysis is static, but the continuous innovation process observed in some industrial sectors, can be seen as a succession of innovation races for different technologies or products. In this case, the success at one step will give an advantage to the winner for further research by allowing an important acquisition of new competencies. This will be particularly true in the case of research workforce. The success of Defence-related firms in a highly competitive and technological context requires a constant investment in R&D. From the theoretical results obtained above, we know that this situation is directly correlated with a large skilled labour demand. But, this analysis takes also many other variables as exogenous, this will lead to great uncertainty on the benefits of the research at each step of the history.

In what follows, we will test this proposition on a sample of French Defence-related firms. We will try to evaluate the positive relationship between innovative capabilities and highly skilled workforce recruitment. We hypothesise that the more plausible is the success of a firm in the innovation race, the easier is their recruitment.

4. the database

It exists two major difficulties in testing such an hypothesis. First, It is problematical to define an accurate proxy for innovative capabilities. Internal R&D spending seem too narrow to encompass all elements of potential success. Second, the definition of an econometric test in order to take into account the link between innovation and recruitment can be hard to define. The solution to both difficulties can be found by using qualitative data. We will first present the sources of the database used in the next section. Then, we would discuss the characteristics of firms and the descriptive statistics of main variables.

4.1. <u>the building of the database</u>

All the data used in the econometric part come from two surveys of the French ministry for industry. The first survey, *innovation 97* or *CIS2*, corresponds to the French part of the second European survey on innovation, it gives information on past innovations, their goals and means and also potential difficulties. The second one, *compétences pour innover*, asked firms if they possess or not 73 elementary skills, potentially useful for innovation. Both surveys are based on large samples of French manufacturing industries and have been conducted in 1997. The survey is exhaustive for firms with a workforce above 500. For firms between 20 and 500, there is a representative poll. As we need answers to both surveys, we restrict the database to firms which answered both. It represents 3415 firms.

The last element of the database is the identification of firms belonging to the Defence industrial base (DIB). As Dunne (1995) said, its scope depends on the question asked. The methodological choice is to include both prime contractors and sub-contractors. It is obvious that innovation in a component of a military equipment will make the whole good more efficient. That's why firms are defined as *Defence-related* on a large scale. On 3415 firms in our sample, 904 belong to the French DIB. The source of such information is a database developed by the French ministry of Defence.

The missing observations are replaced by other statistical sources to obtain a full set of variables on individual capabilities to innovate or to recruit for firms. A major question remain about this database, does the firms belonging to the DIB differ from their counterpart? And more precisely, does this affect their innovative and recruiting behaviour?

4.2. <u>Descriptive statistics</u>

The following table presents the distribution of firms according to their size, their activity and technology, both for the full sample and the DIB.

Table 1	Total (N= 3415)		DIB (N= 904)	
Variables	Number of firms	Percentage*	Number of firms	Percentage*
Manpower				
Less than 50	1425	41.7	203	22.5
50 à 99	536	15.7	102	11.3
100 à 199	346	10.1	95	10.5
200 à 499	439	12.9	152	19.8
500 à 999	385	11.3	178	19.7
1000 à 1999	180	5.3	94	10.4
2000 and more	104	3.1	80	8.9
Business sector				
Comsumption goods	861	25.2	67	7.4
Automobile	118	3.5	58	6.4
Equipment goods	789	23.1	317	35.1
Intermediary goods	1647	48.2	462	51.1
technologic Intensity				
weak technology	1435	42	231	25.6
mean weak tech.	1155	33.8	319	35.3
Mean high tech.	595	17.4	226	25
High technology	230	6.7	128	14.2

The main result of the table 1 is the specificity of firms belonging to the DIB for each distribution. In terms of manpower, firms of the DIB are much larger. Less than 15% of smaller firms (less than 50 employees) belong to the DIB. At the opposite, more than the half of firms between 1000 and 2000 employees are working directly, or not, with the French ministry of Defence. Even more, hardly 80% of larger firms (2000 employees and above) belong to it. This leads us to consider that hardly all biggest French groups are working for the Defence minister.

Moreover, firms of the DIB are concentrated in some industrial sectors. There is much less firms from the consumption goods sector and more in automobile and equipment sectors. Even if automobile constitutes a small part of the DIB, the half of the sector is defence-related. There is an exception in the consumption goods sector, pharmacy, which is largely represented in the DIB. It is largely due to new threats. The main sectors represented in the DIB are aeronautics, shipbuilding and electronics. About the technologic intensity, there is only a few firms with low technology. But half of high tech firms identified in the database are linked with the French ministry of Defence. These firms represent hardly 15% of the defence-related firms, this represent a much larger share than in the total database.

Even if the distribution of firms from the DIB appears quite specific, all categories are represented. Especially, the smallest firms, i.e. less than 50 employees, represent 22.5% of the DIB. It differs from the casual view of the Defence industrial base restricted to prime contractors, *i.e.* big groups specialised in armaments and electronics. The introduction in the analysis of the sub-contractors lead to a larger definition of the link with the Defence procurement. This wider perimeter allows us to take into consideration all sources of innovation in the military equipment. Statistical analysis allow us to conclude that the specificity of Defence-related firms are largely due to the differences in size and sector.

Table 2

Variables	Total (N=3415)		BITD (N=904)	
	Number	Mean	Number	Mean
Public funds (out of crédits d'impôt) to innovate	434	12.7	206	22.8
At least one patent request during the last three years	839	24.6	394	43.6
Cooperation agreement to innovate	872	25.5	399	44.1
Certification ISO 9000	1698	49.7	724	80.1
Evaluation of the technologic situation of the firm	1142	33.4	377	41.7
Evaluation of the personnel skills	2139	62.6	692	76.5
Firm structured around innovative projects	1580	46.3	475	52.5
Evaluation of rival technologies	2715	79.5	809	89.5
Technologic watch	1860	54.5	636	70.4
Test of competing technologies	1274	37.3	435	48.1
Internal spending on Research and development	1402	41.1	561	62.1
Delegation or acquisition of R&D	1024	30	405	44.8
R&D in cooperation with other firms	1089	31.9	453	50.1
R&D in cooperation with public research institutions	873	25.6	377	41.7
Use of patents or license	932	27.3	353	39
Takeover of a firm to innovate	413	12.1	183	20.2
Involvement in joint-venture or strategic agreements	717	21	330	36.5
Sub contractor for highly technologic components	476	13.9	287	31.7
Absorption of knowledge included in components	845	24.7	357	39.5
Identification of strategic knowledge and know-how	1711	50.1	589	65.2
Identification of people having strategic knowledge	1593	46.6	550	60.8
Increasing awarness of the strategic feature of knowledge	1743	51	581	64.3
Control over strategic knowledge communication	1272	37.2	481	53.2
Specific motivation of people having strategic knowledge	1325	38.8	452	50
Guarantee against knowledge loss in case of departure	1455	42.6	497	55

For each variable in table 2, the percentage of firms having the characteristic is always higher in the DIB sub sample. All variables are dichotomous, so the mean of the variables is equal by definition to the probability that a firm possess this character. Comparing both sample, we can see that half of firms which have been publicly funded or which asked for a patent belong to the Defence industrial base. Hardly a third of our Defence sub-sample is a sub-contractor for highly technologic component. This shows that our analysis does not amount to prime contractors. But the DIB gathers 60% of such sub-contractors. Another big difference is the quality certification (ISO9000), the half of the sample is engaged in such a procedure but four firms out of five are concerned in the restricted sub-sample. There exists specific certifications for military procurement which could help to obtain ISO norm. 90% of Defence-related firms evaluate the competing technology, this constitutes an indication of competitive forces in those markets. Defence related firms are making more frequently R&D than their counterparts. There is, even, wider differences in delegation or cooperation of R&D both with other firms and public institutions.

The dependent variables used in the following section are defined as follows:

INNOV = *1* if the firm innovated in product or process during the last three years;
= *0* otherwise

RECRUT = *1* if the firm recruits highly skilled manpower to innovate, = *0* otherwise

Due to the formulation of questions, the second one can't explain the first. So, we respect completely the framework of our model. The econometric estimation will determine jointly the arguments of the innovative past of the firm and its recruitment capabilities. Considering both variables, the distribution of firms is:

total			INNOV	
		0	1	Σ
RECRUT	0	1292 (37.8%)	1248 (36.5%)	2540 (74.4%)
	1	94 (2.8%)	781 (22.9%)	875 (25.6%)
	Σ	1386 (40.6%)	2029 (59.4%)	3415

The most striking feature of these statistics is that 2.8% of firms are recruiting highly qualified manpower to innovate without previous innovation. Three out of five firms innovated in the past three years. This is more than the results obtained in the whole "innovation" survey. A quarter of the sample is recruiting new competencies to innovate. The results for the sub sample defence are somehow different.

sandie			INNOV	
		0	1	Σ
RECRUT	0	199 (22%)	331 (36.6%)	530 (58.6%)
	1	22 (2.4%)	352 (38.9%)	374 (41.4%)
	Σ	221 (24.4%)	683 (75.6%)	904

In the sample of both studies on innovation, the sub sample of Defence related firms shows some differences. Three out of four firms innovated and two out of five recruits highly qualified manpower. The most frequent situation is a firm which innovated and recruits new skills. At the opposite, in the full sample, the most frequent situation in the complete sample is a firm which didn't innovate and don't recruit. Firms related with the Defence sector are more innovative and attract more skilled people than their counterparts.

5. Econometric results

The aim of this section is to test the positive relationship between innovative capabilities of firms and the ease of highly skilled recruitment in order to innovate. The model of the section 3 concludes that both propositions are positively correlated. Thanks to the database presented previously, it is possible to estimate a bivariate probit. It seems the best formalisation to take into account the qualitative character of the data. Thanks to the explanatory variables, we are able to evaluate probabilities of past innovation and of recruitment. To obtain the correlation coefficient between both arguments and in order to be able to discriminate between DIB and "civil" firms, we add the innovation dummy as an explanatory variable in the recruitment equation. Firstly, we present the principle of the bivariate probit and secondly, we comment the results obtained.

5.1. <u>bivariate probit model</u>

This model is the best solution for multiple-equations solving in case of qualitative dependent variables. It corresponds to the estimation of two simultaneous probits equations with correlated disturbances. In this framework, we are able to find the arguments which influence the success in both propositions and to test the correlation of the disturbances.

Let $INNOV^*_i$ and $RECRUT^*_i$ two unobservable variables showing the "interest" or "capabilities" for innovation and highly skilled manpower recruitment. There exists an explanatory variables vector for each dependent variable. The general specification for this two-equation model is:

$$\begin{cases} INNOV^*_i = X_{iI}\beta_I + u_{iI} \\ RECRUT^*_i = X_{iR}\beta_R + u_{iR} \end{cases}$$

where $E[u_{iI}] = E[u_{iR}] = 0$

$Var[u_{iI}] = Var[u_{iR}] = 1$

$Cov[u_{iI}, u_{iR}] = \rho$

Even if $INNOV^*_i$ and $RECRUT^*_i$ are unobservable, we know if a firm innovated or not and if it recruits or not. We have then two dichotomous variables defined as:

$INNOV_i = 1$ if $INNOV^*_i > 0$ $INNOV_i = 0$ otherwise

$RECRUT_i = 1$ if $RECRUT^*_i > 0$ $RECRUT_i = 0$ otherwise

The bivariate normal cdf allows us to define the probabilities to write the likelihood function. The estimation is therefore based on the maximum log-likelihood procedure, details can be found in Greene (2000) and Margolis (2000). In order to evaluate the link between innovation and recruitment, we introduce as explanatory variables in the recruitment equation both the innovative dummy and the cross term between innovation and the DIB, *ie* this dummy will be "1" if, and only if, the firm is innovative and belongs to the DIB at the same time.

5.2. results

table 3 : results with the largest definition of DIB[1]

	INNOV		RECRUT	
Variables	Coeff.	Student' t	Coeff.	Student' t
Intercept	-1.5721	-11.37***	-2.9297	-15.10***
Log (manpower)	0.0841	3.252**	0.1040	3.824***
Certification ISO 9000	0.1848	2.983**	0.1956	2.840***
Firm structured around innovative projects	0.4272	7.765***	0.3367	4.822***
Public funds (out of "crédits d'impôt") to innovate	0.2395	2.330**	0.2004	2.523**
At least one patent request during the last three years	0.6946	7.636***		
Evaluation of rival technologies	0.2590	3.549***		
Technologic watch	0.1365	2.255**		
Test of competing technologies	0.1350	2.206**		
Internal spending on Research and development	0.6822	10.16***	0.2830	2.665***
Delegation or acquisition of R&D	-0.0063	-0.087ns	-0.1084	-1.626ns
R&D in cooperation with other firms	-0.0556	-0.769ns	0.0091	0.134ns
R&D in cooperation with public research institutions	0.3131	3.806***	0.4825	6.464***
Use of patents or license	0.0923	1.345ns	0.2159	3.332***
Takeover of a firm to innovate	0.2315	2.449**		
Involvement in joint-venture or strategic agreements	0.1855	2.213**		
Sub contractor for highly technologic components	0.2159	2.428**		
Absorption of knowledge included in components	0.2523	3.283***		
Identification of people having strategic knowledge			0.0835	1.192ns
Increasing awarness of the strategic feature of knowledge			0.1980	2.677***
Control over strategic knowledge communication			0.1243	1.749*
Specific motivation of people having strategic knowledge			0.1464	2.263**
Guarantee against knowledge loss in case of departure			0.1510	2.341**
INNOV			0.9860	4.863***
INNODIB			0.0550	0.720ns
Correlation coefficient	-0.482 (t=-4.197***)			
Number of observations	3415			
Log likelihood	-2731.863			
Pseudo-R²	0.317			

*** significant at 1% level, ** significant at 5% level, * significant at 10% level, ns non significant

[1] Tables 3 et 4 include sectorial dummies, their results are not reproduced.

Results of table 3 don't reject the theoretical proposition of section 3 of a close connection between past innovations and recruitment in order to innovate in the future. The coefficient associated with the innovation dummy is stricly positive and highly significant. This means that past innovation, used here as a proxy of innovative capabilities, has a positive influence on the probability of recruiting highly skilled people. But the cross term between innovation and DIB is not significant. This means that the link between innovation and acquisition of new skills do not differ between firms belonging to the DIB and their civil counterparts.

Two wide range of explanations can explain this result. Even if the model of the innovation race applies well to the situation of Defence-related firms, their whole industrial sectors have approximately the same industrial organisation. Their specificity come from the sources of their industrial organisation (innovation-driven, monopsony for example) rather than the from their I.O. itself. The second range of explanations is the wide definition of Defence industrial base adopted here. In table 3, more than a quarter of firms surveyed are identified as Defence-related. It encompasses firms which are non-directly connected with the French ministry of Defence (subcontractors) or firms for which Defence market is a very little part of their business, but also firms procuring non-differentiated components or goods for which innovation is, at least, less crucial. It would be of major interest to study the preceding relation on a restricted definition of DIB, this will be done in table 4.

Table 3 gives information about the explanatory variables influencing both probabilities of innovation and recruitment. As previously found in the empirical literature, the size of the firm and the existence of an internal structure of research and development have a positive and highly significant effect on both probabilities. Public funds and research co-operation with public laboratories are also enhancing the performance of firms. This is of major interest for Defence-related firms, which are largely involved in such relationships. But many other arguments can have a positive impact on these capabilities. The ISO certification (international standards of process and product quality) or the internal organisation toward the innovation process are also positively related with the dependant variables. Other important results are obtained about exchange, collaboration and knowledge spillovers ; external procurement of R&D results and collaboration with other firms do not significantly influence probabilities, but formal agreements on research such as joint-venture, *ie* a shared subsidiary dedicated to R&D, have a positive and significant impact. Some other variables can influence the probability of past innovation, the objective is to check the different way of acquiring knowledge about research and innovation by competitors and partners. All features, technological watch, evaluation of competitive technologies… have a positive and significative impact. But without surprise, the use of others innovation by a firm doesn't enhance its own innovation capability.

The second equation also deals with specific arguments, taking into account the effects of human resources and knowledge management in order to innovate. The coefficient associated with the identification of people having strategic knowledge is not significant. It means that this has no impact on the probability of recruiting highly skilled people, which constitutes a striking result. At least, it can imply that this feature is a necessary condition to recruit but not a sufficient one, further investigation will be needed. On the contrary, specific motivation of these people is both positive and significant at 5% level. A better wage or a faster promotion scheme for people having strategic knowledge enhance the firm' capability to acquire and retain new skills. A specific incentive scheme for people having human capital useful to the innovation process of the firm, increase the probability of attracting these workers. At the same time, the control over this knowledge and the awareness about its strategic feature are positively and strongly related to recruitment' probability. The management policy for highly competent people involved in the innovation process in recruiting firms is a "skills and strategic knowledge" management policy rather than a "classical" human resources organisation. The next table is hardly the same as table 3, except for the definition of the link with the French ministry of Defence.

Table 4 : Results with a restrictive version of DIB

Variables	INNOV Coeff.	INNOV Student' t	RECRUT Coeff.	RECRUT Student' t
Intercept	-1.5716	-11.373***	-2.9014	-14.965***
Log (manpower)	0.0842	3.260***	0.0992	3.696***
Certification ISO 9000	0.1834	2.959***	0.1989	2.919***
Firm structured around innovative projects	0.4258	7.740***	0.3301	4.756***
Public funds (out of crédits d'impôt) to innovate	0.2442	2.379**	0.1762	2.195**
At least one patent request during the last three years	0.6928	7.636***		
Evaluation of rival technologies	0.2577	3.535***		
Technologic watch	0.1383	2.290**		
Test of competing technologies	0.1337	2.191**		
Internal spending on Research and development	0.6818	10.153***	0.2686	2.557**
Delegation or acquisition of R&D	-0.0083	-0.116 ns	-0.1081	-1.626 ns
R&D in cooperation with other firms	-0.0557	-0.771 ns	0.0042	0.061 ns
R&D in cooperation with public research institutions	0.3137	3.818***	0.4695	6.272***
Use of patents or license	0.0913	1.331 ns	0.2127	3.284***
Takeover of a firm to innovate	0.2355	2.504**		
Involvement in joint-venture or strategic agreements	0.1891	2.263**		
Sub contractor for highly technologic components	0.2173	2.451**		
Absorption of knowledge included in components	0.2515	3.284***		
Identification of people having strategic knowledge			0.0805	1.151 ns
Increasing awarness of the strategic feature of knowledge			0.1932	2.619***
Control over strategic knowledge communication			0.1260	1.781*
Specific motivation of people having strategic knowledge			0.1430	2.222**
Guarantee against knowledge loss in case of departure			0.1470	2.286**
INNOV			1.0417	5.328***
INNORDDEF			0.4124	2.034**
Correlation coefficient	-0.508 (t=-4.576***)			
Number of observations	3415			
Log likelihood	-2729.947			
Pseudo-R²	0.318			

On the whole, results in tables 3 & 4 are approximately identical. Except for innovation coefficients in the recruitment equation, there is no major changes either in coefficients or in their associated Student t-tests. The restrictive view of the link with the Defence ministry is defined here by a strong assumption. Only firms which obtained a research contract from the Defence ministry between 1992 and 2000 are considered as "Defence-related". This is a clear and direct proxy of the importance of the innovation of this firm for the Defence ministry. But it corresponds to only a small number of firms, 79 in our sample. This is a very restrictive sample compared to the preceding definition, these two definitions correspond to the two extreme cases of the notion of DIB. Contrary to table 3, the cross term between innovation and the belonging to DIB (INNORDDEF) appears to be both highly positive and significant at 5% level. Among innovative firms, there is a stronger relationship between innovation capabilities and their recruiting behaviour for firms contracting with the ministry on R&D topics. Everything else fixed, an innovative Defence-related firm has an higher probability of recruiting highly skilled people than its "civil" counterparts. Their innovation process relies relatively more on a structured R&D with dedicated people especially researchers and engineers and infrastructures, this is a knowledge intensive way of innovation. Does this result show an eventual specificity of the innovation process for Defence-related firms? If we consider that the answer is yes, then we have to think about the scope of the DIB for investigating research and innovation "useful" for Defence provision.

Results obtained in tables 3 & 4 suggest that it exists different degrees of connections between innovation and recruitment behaviours with respect to belonging to DIB. According to both tables, the innovative past of the firm influence positively and significantly the acquisition of human capital in order to innovate. This is particularly true for firms contracting directly on technological topics with the ministry of Defence. Due to the importance of innovation in the Defence industrial base, as shown in the descriptive statistics, the need of highly skilled people is a key element of future success for these firms. But another question appears following these results: what is the right scope of DIB in order to take into account the innovation useful for Defence (Dunne 1995), and then is there a specificity of its recruiting behaviour?

6. Conclusions

In the Defence industrial base, the acquisition of skills deeply depends on the competitive and technologic context. In order to take into consideration all characteristics of highly skilled labour demand, we have to make some hypotheses. Gibbs (2001) concludes that strategic skills in the Defence-related firms are mainly sector-specific. So, we use the concept of “transferable” skills developed by Stevens (1994,96). The labour market for such skills is then an oligopsony. There exists contractual or personal constraints on mobility for people having strategic knowledge. Both hypotheses lead to important imperfections on the labour market.

As the final demand comes from the government only, the market for military equipment takes the form of a national monopsony. This is due to the need of compatibity, and interchangeability for Defence goods. As technological advance is the key argument in the attribution of a contract, the first firm which introduces an innovation will obtain an exclusive contract with the government. Only one firm will be able to make profit out of an innovation. The competitive context will take the form of an innovation race. This leads to strong participation constraints, and technological leadership is likely to emerge. If an highly skilled workforce is a crucial argument to enhance the probability of innovation, the model of the section 3 shows that the opposite is also true. Innovative capabilities, approximate in our empirical test by the determinants of success in past innovations, can have an effect on the recruitment of highly skilled manpower. The main proposition is the existence of a positive correlation between innovation capabilities and highly skilled manpower recruitment.

This proposition is tested on a sample of French firms belonging to manufacturing industries. The data come from two surveys on innovation conducted in 1997 by the French ministry of industry. They permit to have a large view on every elements of the innovation process thanks to qualitative data. The identification of Defence related firms is allowed thanks to a filter from the French ministry of Defence. The econometric test is based on a bivariate probit. It allows us to consider at the same time the arguments of probabilities of past innovation and of recruitment, but also the correlation coefficient between both equations. The descriptive statistics have shown that Defence-related firms are larger, of higher technology and more specialised than the whole industry.

The econometric results don’t reject the theoretical proposition. The link between past innovation and recruitment appears both positive and significant for the whole sample, but the specific behaviour of DIB is not obvious and will need further investigation. The main explicative variables for both probabilities are of course the presence of a research structure, the size of the firm but also the organisation of the firm and the co-operation with public research institutions. The innovative past plays a more important role on recruitment for Defence-related firms. This would induce a stable stock of competencies in some firms which have a technological advance. This process could may be explain the mergers observed in such sectors, the leader strengthening its position by the acquisition of new skills Past innovations ease further recruitment which are in turn a necessary condition for future innovation. The uncertainty is still present because of the possibility of breaking innovations such as unmanned air vehicles (UAV) which are partly substitutes for observation aircrafts.

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