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HOW COMPETITION AFFECT INNOVATION BEHAVIOUR IN FRENCH FIRMS ?[1]

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ABSTRACT

This paper investigates the relationship between competition and innovation at the firm level. Recent papers (Aghion, Bloom, Blundell, Griffith and Howitt, 2005; Askenazy, Cahn and Irac, 2013; or Rafique Hashmi, 2013) advocate a non-linear relationship, conciliating the Schumpeterian and Arrowian view of this relationship. In this study, the effect of competition on innovations is studied at the firm level using a datasets for France coming from the annual surveys on R&D, covering the period 2000-2013 A dummy variable is available for the product or the process innovations. The econometric results confirm the inverted U-shape relationship between competition and innovation. However, for most of the firms, there is a negative effect of competition on innovation, meaning that more competition in the industry or a small market share of the firm has a negative effect on the propensity to innovate, either in product than in process. The effect is stronger for product innovation rather for process innovation.

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1. INTRODUCTION

Innovations are generally considered as a major determinant of the firm's performance and consequently of the growth of a country. The innovations improve the firm's profitability by lowering its production costs and by giving a market advantage with respect to its competitors.

There is a large empirical literature showing that the innovation behavior can be determined by differences in market power or in concentration in industry. In 1994, Aghion and Tirole mentioned that the relationship between firm size or industry concentration and R&D or innovations was the second most tested hypothesis in empirical industrial organization. The literature surveyed by Cohen and Levin (1989) or by Gilbert (2006) for example, mentioned also a lot of empirical studies on this topic on different countries and different periods, with also different structure of data: firm, industry or country level. There is also a lot of measure of innovation: the inputs to innovation like R&D or technological expenditures, or the outputs of innovation: number of major innovations, patents, or answers to innovation surveys.

Schumpeter (1934) advocated that more competition in a market has negative effects on innovation. Large firms innovate more because they are more stable, they have more internal funds to invest in innovation, and they can protect more easily their innovations. The inverse argument that competition is better for innovation was first presented by Arrow (1962). A monopoly has less incentive to innovate because it can lose the monopoly rents if a new product or a new technology is introduced by its competitors. There is a large literature[3] in industrial organization on the incentives to innovate focusing on the appropriability of innovations, the size of innovation, the obsolescence of old products, or on the uncertainty of the innovation outcomes.

Some firms want to keep a market advantage by continuously proposing new products to consumers. Other firms want to improve the production process in order to save inputs, time or labor reducing the cost of goods. The link between competition and firm's innovations has been documented by Aghion et al. (2005) with an inverted U-shape relationship for the U.K. But this curve has been questioned by several authors: for example in the U.S by Rafique Hashmi (2013), in Canada by Tang (2005), in the U.K by Correa (2012) or in France by Askenazy et al. (2013)

Some economists argue that success breeds success, and that innovations can lead to more innovations in the future because firm knows how to satisfy the consumers with new product, and how to save costs in production. Therefore the persistence of innovation can be the sign of a true-state dependence: the decision to innovate will raise the probability to be innovator in the next periods. This is an autoregressive discrete process.

Schumpeter outlined the role of the technology in the survival of the firms. The process of creative destruction leads to the replacement of old firms by new firms with innovative products. Therefore the innovation is rather an accident in the firm's life where a new innovative firm takes the place of installed firms (see Aghion and Howitt, 1992). Romer (1990) sustains the assumption that the process of innovation is quite persistent at the firm level.

[3] See the surveys by Gilbert (2006).

The innovation behavior can be also due to specific characteristics of the firm: the type of product, the quality of its management, the effectiveness of its labor force, the organization within the firm; or the characteristics of competition: concentration, leadership of the firm. Those characteristics are generally unobserved at the firm level and often largely correlated across the periods. Thus it is important to measure this unobserved heterogeneity which can affect the persistence of the innovation behavior. The question is to know what part of the persistence is due to the true-state dependence or to the unobserved heterogeneity. This has many policy implications on how to foster innovations in a knowledge-driven economy (see Peeters, 2009).

There are still a lot of studies about the persistence of the innovations at the firm level. The first stream of studies: Geroski, Van Reenen and Walters (1997) for the UK, Cefis (2003) for the U.K., Mallerba and Orsenigo (1999) or Cefis and Orsenigo (2001) for six European countries, Huang (2008) for Taiwan uses the patents as the measure of innovations. A second type of studies use a direct measure coming from surveys, like the Community Innovation Surveys (CIS), as defined in the Oslo Manual (OCDE, 1994). Let us quote for example, Flaig and Stadler (1994) for Germany, Duguet and Mojon (2002) for France, Peters (2005) for Germany, Roper and Hewitt-Dundas (2008) for Ireland or Triguero-Cano and Corcoles-Gonzalez (2009) for Spain. Finally in more recent studies, some authors use the share of innovative sales can be used as a quantitative measure of product innovation : Peters (2009) for Germany, Raymond, Mohnen, Palm and Schim van der Loef (2010) for the Netherlands or Roper and Hewitt-Dundas (2008) for Ireland.

There are also different statistical and econometric methodologies used in these studies of the persistence of the innovation behavior. Geroski, Van Reenen and Walters (1997), Mallerba and Orsenigo (1999) did a survival analysis in the innovative activity for the firms. Cefis (2003), Cefis and Orsenigo (2001), Roper and Hewitt-Dundas (2008) for Ireland use the transition matrices between two periods with the estimation of an autoregressive process. Flaig and Stadler (1994), Peters (2005), Huang (2008), Triguero-Cano and Corcoles-Gonzalez (2009) estimated a random effect probit model for the indicator of innovation, while Peters (2009) and Raymond, Mohnen, Palm and Schim van der Loef (2010) tried to fit a dynamic tobit model for the share of innovative sales. Finally Duguet and Mojon (2002) used a different methodology based on the propensity score matching in order to assess the difference between innovators and non-innovators.

This paper investigates the relationship between competition and innovation and the persistence of innovation behavior at the firm level. We want to study how the concentration measures of firms in a market have an effect on innovations at the firm level by using a new datasets for France coming from the annual surveys on R&D, covering the period 1999-2013, where a dummy variable is available for the product or the process innovations. This datasets is comparable to the German data used by Peters (2005, 2009) because the data are collected on an annual basis in the form of a panel. Unfortunately for France, we have no information on the innovative sales. On the other hands, French firms are asked to distinguish between product and process innovations. Therefore we can also investigate the cross-dependence between both types of innovations.

A random effect probit model for product and process innovation is estimated including a measure of concentration of the industry where the firm operates. As in Aghion, Bloom, Blundell, Griffiths and Howitt (2005) (henceforth ABBGH), or in Askenay, Cahn and Irac (2013) (henceforth ACI), the competition index is based on the Lerner index. A second effect of the competition on innovations is the position of the firm within its market, measured by its market share or the leader position as in Blundell, Griffiths and Van Reenen (1999). We want also show the relative position of the firm in terms of efficiency by computing a distance to the frontier of efficiency based on total factor productivity like in ABBGH or in Rafique Hashmi (2013).

2. Innovation in the French R&D Surveys

The 1999 reform of the R&D surveys in France introduced two new question s about the product or the process. These question are the following:

> *"During the year, did your enterprise or your group introduce new or significantly improved goods coming from the R&D activity of your firm ?" – Yes or No*

> *"During the year, did your enterprise or your group introduce new or significantly improved methods of manufacturing or producing goods or services coming from the R&D activity of your firm ?" – Yes or No*

These questions are slightly different from the usual CIS questionnaire because in the latter the time period is prolonged over 3 years. For examples in the CIS 2004 questions, the first words are replaced by "*During the three years 2002 to 2004,...*". Moreover in the French R&D surveys, only innovations coming from the R&D done by the firm itself are considered. That excludes the innovations which were introduced without any R&D effort. On the other hand, the product or process innovations can be done by another firm in the group. This is why the answers to the CIS surveys and the R&D surveys are not directly comparable. But the most important difference is that in CIS surveys, the innovations are accounted for on the three years period. If we neglect who introduces or uses the innovations due to the R&D of the firm, we could reconstruct the CIS innovation indicator by looking to the R&D surveys. A firm is an innovator from the CIS point of view, if it introduces at least one innovation on the current year and the past two years. But the converse is impossible, we cannot reconstruct the annual innovation indicators in the R&D surveys on the basis of the CIS innovations indicators over three years because we cannot disaggregate the measure on the three years.

A second problem comes from the fact that firms has many difficulties to disentangle product or process innovations, even though the definitions from the Oslo manual are quite precise (see the discussion in Mairesse and Mohnen, 2001). When a firm introduces a new product on the market, it changes and improves also the methods of production. Therefore, the product and process innovations are linked together at the firm level. Even though this problem of measurement is a serious one, we will consider both types of innovations in the following. While there are some firms which innovates only in product or in process, the statistical difference between both types of innovations are thin. There are also cross relationships between product and process innovations.

The unbalanced sample of the French R&D surveys covers a 14 years period: from 2000 to 2013 with are 9 374 firms, corresponding to 48 520 observations. As mentioned above, only firms with at least 3 consecutive years of data are retained in the sample. But as the lagged value of innovations dummies is used in the estimation, the first year of observation of each firm is dropped out. The Appendix A provides the number of observations and firms by industry and size.

Over the whole period 2000 - 2013, 58.5 % of firms introduce a product innovation, and 55.1 % a process innovation. Moreover 45.7 % of firms report both product and process innovations, while 32.1 % do not report none innovations during the year. The innovations are very frequent in our sample of firms doing a formal R&D activity. Therefore only 22.2 % of firms report only one type of innovations, which seems to agree with the Mairesse and Mohnen (2001) critics. The Figure 1 shows the shares of product or process innovator in the sample weighted by the total employment of the firm. Large firms are doing both types of innovation more frequently than small firms. The innovators exhibit an upward trend during the period. The share of product innovators is larger than the share of process innovators except in 2003, 2004 and 2006. But the difference between the product and process innovators is quite small. The effect of the 2008-2009 big recession is shown only in 2010 and 2011 with a lag of two years in both product or process innovations where the rate of innovators is lower than in the period 2009. Let us also note the large decrease in the process innovation in 2013, which is due mainly to firms in services where the share of process innovators falls down by 30 % in 2013 while the share of product innovators remains roughly the same relative to 2012.

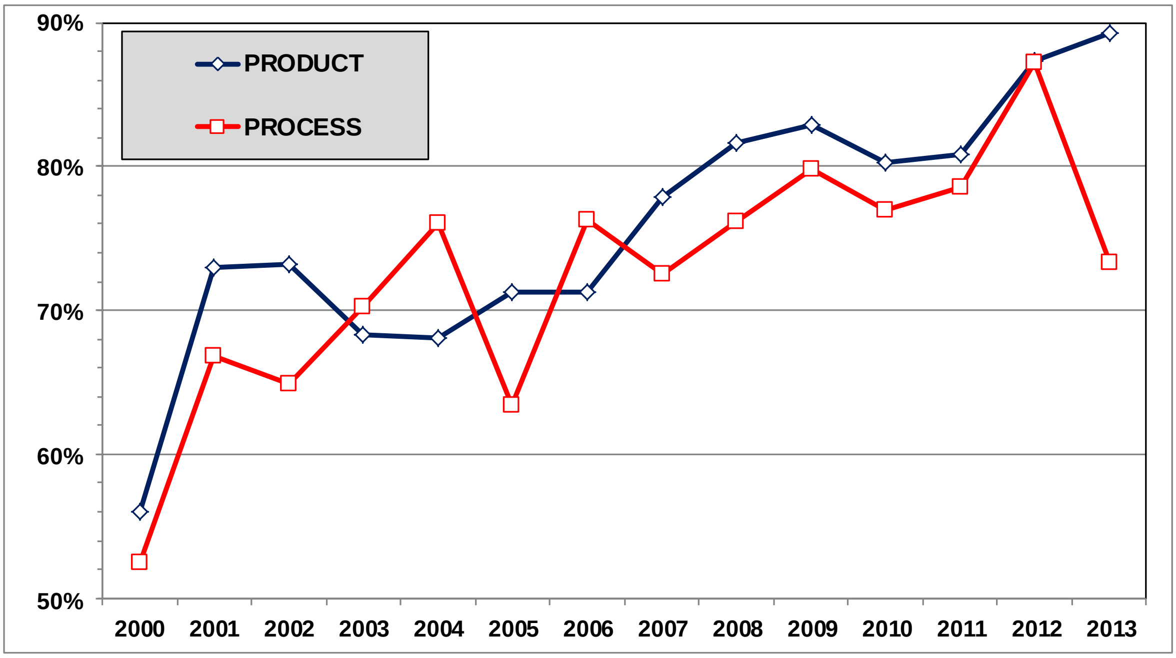


Figure 1 : Share of Product or Process Innovators
(Unbalanced sample – weighted by total employment)

As shown in Table 1, the unweighted share of innovators is approximately the same in manufacturing industries or in services with a slightly higher number of product innovators in manufacturing industries. This is due to the fact that the firms in services are mainly firms in business support services like software, communication, technical or R&D activities (see appendix A for a detailed composition of the sample) where the innovations are usual in the business because it is easy to do an incremental innovation in the firm's supply. However when the innovations are weighted by the firm's employment, the share of innovators increases in both manufacturing and services: this is the well-known size effect that larger firms innovate more than small firms. Moreover this size effect is larger in services than in manufacturing. The weighted share of innovators in product or in process is larger in services by 12 points. The propensity to innovate seems to depend more on the firm's size in servoces than in manufacturing.

PRODUCT INNOVATION			
	MANUFACTURING	SERVICES	ALL FIRMS
Unweighted	59.6%	56.7%	58.5%
Weighted*	71.0%	83.6%	76.4%
PROCESS INNOVATION			
	MANUFACTURING	SERVICES	ALL FIRMS
Unweighted	55.3%	55.0%	55.1%
Weighted*	67.8%	79.9%	73.0%

All firms : 9 374 firms, 48 520 observations, 2000-2013
Manufacturing firms : 5 114 firms, 29 704 observations.
Services firms : 4 260 firms, 18 816 observations.
* : weighted by firm's employment.

Table 1 : Innovation rate (2000 - 2013)

The link between product innovation and process innovation is strong because 67.7% of (weighted) firms are doing simultaneously both types of innovations as shown in Table 2. The second category with 18.3% of (weighted) firms implies no innovation during the year, while the two remaining categories where the firm innovates only in product or in process represent only a marginal share of firms. For the whole sample, the Kendall's τ_b measure of association is very large with 63%. As mentioned by Mairesse and Mohnen (2001), firms has many difficulties to disentangle product or process innovations. When a firm introduces a new product on the market, it changes and improves also the methods of production. Therefore it is possible to question the pertinence of the distinction between product and process innovations. In the econometric estimation, it will be shown that there are many differences in the determinants of both types of innovations.

	None	Only Product	Only Process	Product and Process	Kendall's Tau-b
All firms*	18.3%	8.7%	5.3%	67.7%	63.2%
Manufacturing*	23.0%	9.2%	6.0%	61.9%	64.6%
Services*	12.0%	8.1%	4.4%	75.5%	58.6%

* weighted by firm's employment
Sample : 9 374 firms, 48 520 observations, 2000-2013
Manufacturing firms : 5 114 firms, 29 704 observations.
Services firms : 4 260 firms, 18 816 observations.

Table 2 : Cross - Innovation rate (2000 – 2013)

The following table exhibits the transition of innovation behavior in order to assess the persistence of innovation at the firm level. For both types of innovation, the persistence of innovation or non-innovation is large. Only a minority of firms change their behavior by becoming innovators or stopping their innovations. For product innovation, 60 % of firms stays non-innovator, while 72% of firms stays innovator. Only 40% of firms which was not innovator in product become innovator next year. In opposite way, only 28% of firms stop to be innovator next year. The figures are quite the same for process innovations, where the stable behavior is found for 63% of non-innovator, and for 71% of innovators. The change from non-innovator to innovator concerns only 37% of firms, and 29% for the converse. In France, it seems to be less persistence than in Germany according to Peters (2005) even though the share of innovators is similar in both countries. With this persistence behavior, the firms should belong at long-run to the categories of innovator or non-innovator for both types of innovations. There will be no difference between product and process innovations at the long run. In the econometric estimation, the effect of the direct persistence of innovation will be estimated, as well as the cross-persistence of innovation between the two types of innovation. The question will be to assess the effect of past process innovation on the current product innovation and *vice versa*.

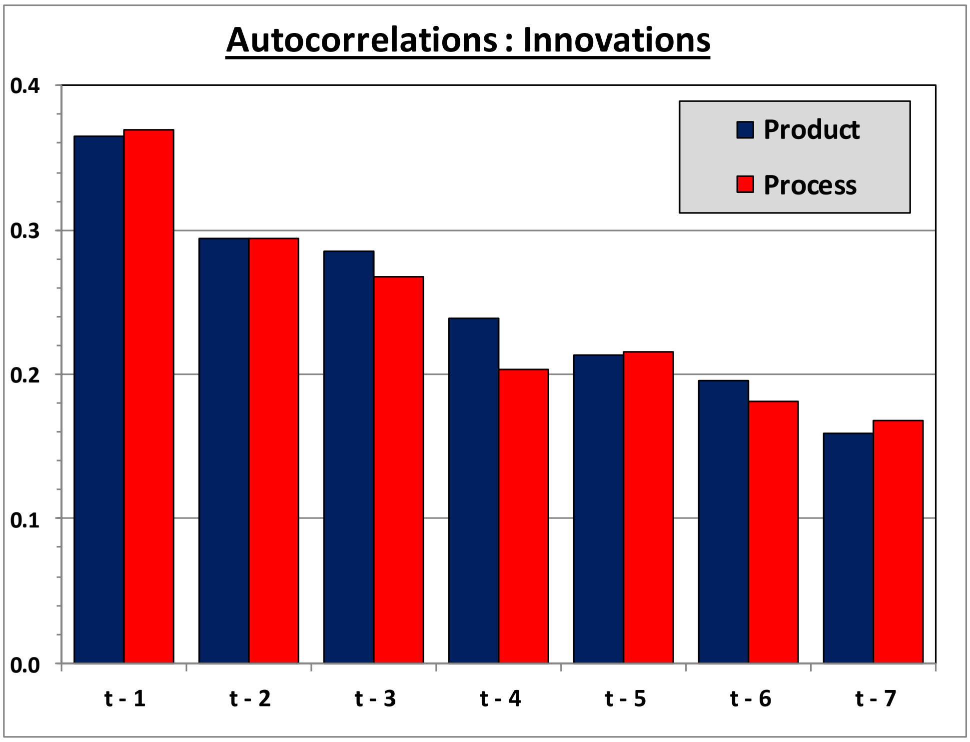
PRODUCT INNOVATION		
	IN YEAR T	
IN YEAR T-1	Non - Innovator	Innovator
Non - Innovator	60.0%	40.0%
Innovator	27.6%	72.4%
TOTAL	41.5%	58.5%

PROCESS INNOVATION		
	IN YEAR T	
IN YEAR T-1	Non - Innovator	Innovator
Non - Innovator	62.7%	37.3%
Innovator	29.4%	70.6%
TOTAL	44.9%	55.1%

Unbalanced sample : 9 374 firms, 48 520 observations, 2000-2013

Table 3 : Transition matrices for Product and Process Innovators

Finally the Figure 2 presents the autocorrelation (up to the seventh order) for the product and process innovation dummies. The raw autocorrelation parameter is the same as the Kendall's τ_b measure of association in a 2x2 contingency table. There is a similar, large autocorrelation in product or process innovations as already shown in Table 3. The aucorrelations decrease smoothly with the lags showing a strong persistence of innovations behavior. There are no significant differences in persistence between product and process innovation. This persistence can be due to a true state dependence in time series data, where the innovation behavior depends on the past behavior. But it can be also the sign of an unobserved heterogeneity between firms. Some firms can have structural characteristics, technological opportunity or management which lead to innovate at each period, while other firms do not have these features. The econometric estimation on the panel data will tend to disentangle the two causes of persistence.



Unbalanced sample : 9 374 firms, 48 520 observations, 2000-2013.

Figure 2 : Correlogram of Product or Process Innovation

3. Measurement of Competition

Several measure of competition is used in many empirical studies on the link between competition and innovation. Geroski (1990) which attempt to test the Schumpeterian hypothesis with a cross-section of industries used the five firms market concentration ratio in the industry, as well as its annual change. He added the market share of exiting firms, the market share of import and the relative number of small firms.

Nickell (1996) in its paper on the relation between competition and corporate performance, measured by its productivity, on a panel of British companies, introduced the market share at the firm level, a measure of concentration and the import penetration of the industry, a survey-based measure of competition perceived by the firm's managers, and a measure of the average rents normalized on value-added. This last measure can be interpreted as price cost margin or a Lerner index as in Aghion et al. (2005).

The market share was also used by Blundell, Griffiths and Van Reenen (1999) in a count model of major innovations in a panel of British firms. They added to their model some variables measured at the industry level such as the four firms market concentration ratio, and the import penetration as in Geroski's study.

In this study, a competition measure is based on the Lerner index computed as in ABBGH or in ACI studies at a three-digit level of industry classification[4]:

$$Lerner = \frac{Operating\ \ Profits - Financial\ Cost}{Sales}$$

The financial cost is usually measured by assuming a unit user cost of capital of 0.085, which multiplies the fixed capital computed by a perpetual inventory method summing investment with a depreciation rate of 8%. The firm's level Lerner index is averaged over the industry for each year in the sample. It can be considered as a measure of the rents coming from the market power of the firms in a given industry. In the following, we transform this Lerner index in a measure of competition as :

$$Compet = 1 - Lerner$$

The range of this variable is between 0 and 1 (perfect competition). Therefore a rise of this variable means an increase in competition. Let us note that this measure of competition characterize the competitive environment of a firm within its industry. Alternative measures of market concentration would be the Hirshman-Herfindhal index (*hhi*), the Gini coefficient (*Gini*) or the four firm concentration ratio (*C4*). However none of them proved to be significant in further estimations.

Other measures of competition are obtained at the individual firm level in order to characterize the position of the firm within its industry (always at a three-digit level). This is the market share based on sales (*mkt_share*). This measure shows not only the size of the firms in its market, but also the number of competitors. Therefore in a concentrated industry with only a few firms, the market share could be large, even if the firm is not the leader in its industry. While in a very large industry with a lot of firms, the leader can have only a small market share. To distinguish the relative position of the firm in its own industry, we have constructed two variables: first a dummy variable (*leader*) for the largest firm within an industry, and a quantitative variable measuring the relative market share (*mkt_rel*) compared to the largest firms in the industry: this variable takes the value one for the leader in the industry, and a value between 0 and 1 for other firms showing the percentage of the sales of the leader

$$mkt\_rel_i = mkt\_share_{leader} - mkt\_share_i$$

This variable show how small is the followers relative to the leader in the industry.

Finally we want to use a measure of the technology gap between firms within an industry. Following ABBGH or Rafique Hasmi (2013), we have computed a relative measure of efficiency at the firm level based on a distance to the technology frontier with an estimate of the total factor productivity *TFP* of the firm. First a production function is estimated at the industry level with labor and capital inputs on a very large sample of more than 100 000 French firms with more than 1 290 000 observatiosn. The total factor productivity *TFP* is then

[4] In fact we use the French NA129 classification (*Nomenclature agrégée en 129 secteurs*), where there are 72 industries in manufacturing, and 39 industries in services.

computed for each firm within the industry. Next we measure the relative distance (as the log difference) with the most efficient firm (TFP_{max}), i.e. the firm having the largest TFP[5].

$$distance_i = \log(TFP_{MAX}) - \log(TFP_i)$$

This variable can be different from the market share of the firm because a firm technologically efficient should be not the largest in its industry. This variable *distance* can also measure the technological proximity of firm within the industry. This is the assumption of a levelled industry (neck-and-neck) in the article by ABBGH, compared to the unlevelled industry with technological gap.

The following tables present the descriptive statistics on these competition measures. The measure of industry competition (*Lerner* or *Compet*) is consistent with an average of the supra-normal profit of 13.2% and a median of 11.2%. However the distribution is clearly asymmetric because 90% of the observations has a Lerner Index smaller than 0.767, and only 3% of observations with a value smaller than 0.500.

The asymmetry is also present for alternative measures of industry concentration. For Hirshman-Herfindhal index, the median is smaller than the mean, and the standard deviation is important. The market share of the four largest firms in an industry accounts in average for 22.4% of the sales of the industry, but the dispersion of the C4 index is large from 1% to 100%.Finally the average Gini coefficient is moderate with 10.4%.

	Mean	Std. Dev.	Min	Median	Max
Lerner	0.1322	0.1059	0.0000	0.1116	0.8129
Compet	0.8678	0.1059	0.1871	0.8884	1.0000
hhi	0.0358	0.0699	0.0001	0.0127	0.9897
Gini	0.1039	0.0488	0.0015	0.0943	0.4589
C4	0.2239	0.1725	0.0109	0.1509	1.0000
mkt_share	0.0075	0.0411	0.0000	0.0006	0.9948
mkt_rel	0.0629	0.1565	0.0002	0.0089	1.0000
leader	0.0102	0.1005	0.0000		1.0000
distance	0.812	0.426	0.000	0.793	3.876

Table 4 : Descriptive Statistics of Competition Measure

The average market share is only 0.75% of the total sales of the industry, with a median market share even lower: 0.06%. This shows a large asymmetry: there is a small number of firms which dominates their industry in terms of sales: only 1% of firms is leader in their industry. Moreover only 1% of observations have a market share larger than 12% of the corresponding industry, and 88% of observations have a market share larger than 1% of the total sales of the industry. The relative market share is on average 6.3% of the sales of the leader in the industry (the median is still weaker with 0.9%). An industry is then composed of

[5] In fact we consider the firm with the 95% centile of the TFP as the most efficient firm. For the firms even larger efficient, the distance to the frontier is set to zero.

a large number of firms where only a few have a significant market share, and the followers are smaller: only 15% of firms reach the threshold of 10% of the leader's sales in the industry.

The average distance to the technology frontier is 0.812. It means that on average the *TFP* of the firm is 44% of the *TFP* of the most efficient firm in the industry. The technology gap measured by this variable is very large and must overestimate the technological inefficiency of the followers. Only 25% of firms have a *TFP* higher than 60% of the *TFP* of the most efficient firm in the industry. The distance to the leader in industry is negatively correlated (- 0.244) with the competition measure (*Compet*), meaning that a larger competition within an industry is associated with a smaller technology gap. The firms within a more competitive industry are closer in terms of technology efficiency.

The last Table 5 present t-tests of the difference in the competition measure between innovators and non-innovators for product or process innovations. Most of the differences are significant due to the large number of observations in the sample. The competition variable (*Compet*) is significantly smaller for the innovator, especially for product innovation. Therefore a larger competition in an industry does not mean a larger propensity to innovate. Moreover the innovators in product or process have a larger market share: the average market share is twice for innovators in product or in process, and the relative market share is 2.8 points larger for innovators. The Schumpetarian hypothesis about the link between competition and innovation seems to be supported by these figures.

PRODUCT INNOVATION					
	NO	YES	Difference	T-stat	P-value
Lerner	0.1174	0.1420	0.0246	-25.81	0.0000
Compet	0.8821	0.8577	-0.0245	25.80	0.0000
hhi	0.0350	0.0364	0.0014	-2.17	0.0302
Gini	0.1066	0.1019	-0.0047	10.30	0.0000
C4	0.2202	0.2265	0.0063	-4.01	0.0001
mkt_share	0.0050	0.0093	0.0042	-11.96	0.0000
mkt_rel	0.0481	0.0749	0.0268	7.49	0.0000
leader	0.0065	0.0128	0.0063	-7.21	0.0000
distance	0.8210	0.8065	-0.0145	3.69	0.0002
PROCESS INNOVATION					
	NO	YES	Difference	T-stat	P-value
Lerner	0.1239	0.1383	0.0144	-14.85	0.0000
Compet	0.8757	0.8614	-0.0143	14.82	0.0000
hhi	0.0361	0.0356	-0.0005	0.81	0.4205
Gini	0.1055	0.1025	-0.0030	6.70	0.0000
C4	0.2236	0.2241	0.0004	-0.27	0.7843
mkt_share	0.0054	0.0093	0.0039	-10.87	0.0000
mkt_rel	0.0481	0.0749	0.0268	-19.37	0.0000
leader	0.0070	0.0128	0.0058	-6.47	0.0000
distance	0.8124	0.8126	0.0002	-0.04	0.9653

Unbalanced sample : 9 374 firms, 48 520 observations, 2000-2013
20 131 Product innovations (41.5%) , 21 769 Product innovations (44.9%)

<u>Table 5 : Difference in Means between Innovators and Non-Innovators</u>

However this conclusion could be attenuated if the alternative measures of concentration are considered. The average C4 concentration ratio is only larger for product innovators even though there is no difference in C4 for process innovation, while the Hirshman-Herfindhal index is hardly different for product innovation and the difference is not significant for process innovation. These competition measures agree with the fact that less competition leads to more innovations. Nevertheless the negative and significant difference in the Gini coefficient between innovators and non-innovators goes in the other direction. A larger Gini coefficient, meaning a greater concentration in the industry, increases the share of product innovator, while it decreases the share of process innovators.

4. The econometric estimations

In this section, a probit model explaining the product and process innovation behavior is estimated on the panel of French firms for the period 2000 – 2013. Even it should be better to use a joint model with contemporaneous correlations, we prefer to estimate two separate probit models with random individual firm's effect.

$$Product_{i,t} = f\left(Product_{i,t-1}, X_{i,t}, Competiton_{i,t-1}, TimeDum., Ind.Effects\right)$$
$$Process_{i,t} = f\left(Process_{i,t-1}, X_{i,t}, Competiton_{i,t-1}, TimeDum., Ind.Effects\right)$$

where *X* is a set of firm's control variables like the size of the firm measured by employment, the capital intensity: the log of capital-labor ratio, the export rate: the share of foreign sales, the R&D intensity: the ratio of R&D expenditures to the total sales. The competition variables are the variable defined above: the competition measure (*Compet*) based on the Lerner index, the market share (*mkt_share*), the relative market share (*mkt_rel*), the leader dummy (*leader*), and the distance to the technology frontier (*distance*). All the competition measures are lagged once because they can be correlated to the current innovations of the firm. We assumed that they can be considered as predetermined.

A full set of year dummies is added to the specification to take account of the general business environment in France common to all firms. Finally individual random effects, assumed to be uncorrelated with the explanatory variables, are introduced in the model to take account of the unobserved firm's characteristics.

The model is a dynamic panel data probit model with individual random effects because the fixed effect specification implies inconsistent probit estimates because of incidental parameters problem (see for example Greene, 2004). The maximum likelihood estimation method relies on the unconditional density functions by integrating out the individual effects which is assumed to be normally distributed. Buttler and Moffitt (1982) have proposed a Gauss-Hermite quadrature in order to evaluate these unconditional densities in panel data probit model.

A second problem arises in a dynamic probit model with individual random effects, because this effect is correlated with the lag values of the dependent variable, here the product or process indicators. In order to obtain consistent estimates, Wooldridge (2005) proposed to approximate the process of the initial observation in order to correct the inconsistency by conditioning on the initial value of the variables. Therefore the initial values of the dependent and explanatory variables are introduced in the estimated model.

The Table 6a and 6b presents the results of estimation for product and process innovations respectively (the full estimation results are presented in Tables in Appendix B). In each case, four regressions are reported. The first one is a simple autoregressive model of innovations without any other explanatory variables. The second regressions introduce the control variables where the square of employment (measured in thousands of employees) and the square of R&D intensity are used in order to take account of a non-linearity in the effect of these variables. The distance to the technology frontier is introduced in a third model, while the fourth specifications include the competition measures. Again a quadratic effect of these variables is tested in the line of the inverted-U shape of competition effect in ABBGH.

The log-likelihood increase significantly between the regressions for product and process innovations, while the standard error of the individual effects decreases, showing that a more complete specification reduces the unobserved heterogeneity and capture a part of the individual characteristics of the firm.

The pure autoregressive model clearly indicates a positive persistent innovation behavior in product and in process. Success in innovation breeds next success. Moreover doing one type of innovation implies a larger incentive to do the other type in the next period. If control variables or competition variables are added up to the pure autoregressive model do not change the estimates of lagged innovation. They are stable across the different specifications.

For the complete models Table 7 gives the average marginal effects for regressions (4). The average marginal direct effect for product innovation is about 0.089; while it is lager for process innovation with 0.124. That means that doing product innovation in the last year increases the probability to do product innovation in the current year by 8.9%, while for process innovation, it rises the probability to innovate in process by 12.4%. The cross persistent marginal effect is about 0.060, meaning that doing a process innovation last year, increases the probability to innovate in product by 6.0%. The inverse is somewhat weaker with an increase by 4.8% in the probability to introduce a process innovation if the firm was doing a product innovation last year.

But the marginal effects of the initial innovation behavior are again larger. If a firm was doing an innovation in product or in process at its initial period, it raises the probability to do a process innovation further by 13.6%, and by 3.0% respectively. The average marginal effects for process innovation are respectively 10.0% for an initial process innovation, and 6.6% for an initial product innovation. These initial effects are important and significant because they capture a large share of permanent innovation behavior at the firm level. But even though there are cross effects of the other types of innovation, the direct effects are larger in the continuous innovation determinants.

PRODUCT	(1)	(2)	(3)	(4)
Log likelihood	-28 201.6	-28 017.6	-27 998.2	-27 906.5
Product (t-1)	0.2607 ***	0.2615 ***	0.2608 ***	0.2650 ***
	(0.0187)	(0.0187)	(0.0187)	(0.0187)
Process (t-1)	0.1871 ***	0.1760 ***	0.1762 ***	0.1775 ***
	(0.0171)	(0.0170)	(0.0170)	(0.0170)
L (t)		0.1102 ***	0.1076 ***	0.0750 *
		(0.0314)	(0.0313)	(0.0395)
L (t-1)		-0.0004	-0.0004	-0.0005
		(0.0004)	(0.0004)	(0.0013)
(R&D / Sales) (t)		0.6777 ***	0.7023 ***	0.8111 ***
		(0.1667)	(0.1666)	(0.1655)
(R&D / Sales)² (t)		-0.6483 ***	-0.6694 ***	-0.7401 ***
		(0.1560)	(0.1559)	(0.1548)
log(K / L) (t)		0.0627 ***	0.0637 ***	0.0428 **
		(0.0177)	(0.0177)	(0.0177)
Export rate (t)		0.2187 ***	0.2094 ***	0.1777 ***
		(0.0501)	(0.0500)	(0.0497)
Distance (t-1)			-0.0518 **	-0.0702 ***
			(0.0237)	(0.0239)
Compet (t-1)				2.4691 ***
				(0.6717)
Compet² (t-1)				-2.6098 ***
				(0.4897)
mkt_share (t-1)				2.7823
				(1.8987)
mkt_share² (t-1)				-4.8940 **
				(2.3193)
mkt_rel (t-1)				1.1692 ***
				(0.3958)
mkt_rel² (t-1)				-1.2240 ***
				(0.3911)
leader (t-1)				0.2518 *
				(0.1384)
σ (alpha)	0.6299 ***	0.6013 ***	0.5988 ***	0.5789 ***
	(0.0143)	(0.0141)	(0.0140)	(0.0139)

All firms : 9 374 firms, 48 520 observations, 2000-2013.
Full set of time dummies and initial value of variables not reported here.
Maximum likelihood estimation of panel probit model using Gauss-Hermite quadrature with 12 integration points. Asymptotic standard errors in parenthesis.
Estimates significant at 1% level : ***, at 5 % level : **, at 10% level :*.

Table 6a : Estimation results : Product Innovation

The size of the firm, the R&D intensity, the capital intensity and the export rate have all a positive effect on the innovation behavior either in product than in process. While there is no attenuation for employment because the quadratic terms is not significant, the effect of R&D intensity weakens and reaches a maximum effect for a R&D intensity by 50% for product innovation and 70% for process innovation. However only a few firms is above these thresholds because the average value of R&D intensity is only 15.4%. Let us note that the R&D intensity has a larger effect for the product innovation than for process innovation where it seems less determined by the R&D expenditures of the firm. The inverse results is found for the capital-labor ratio which has a larger impact on the process innovation than on product innovation even though the difference is quite small and not really significant. Finally the export behavior of the firm seems to have the same effect on both innovations where a 10 percentage point increase in export rate, implies a larger probability to innovate in product or in process by 0.6%.

PROCESS	**(1)**	**(2)**	**(3)**	**(4)**
Log likelihood	-28 742.9	-28 552.9	-28 549.4	-28 494.1
Product (t-1)	0.1542 ***	0.1422 ***	0.1412 ***	0.1375 ***
	(0.0170)	(0.0169)	(0.0169)	(0.0169)
Process (t-1)	0.3533 ***	0.3548 ***	0.3552 ***	0.3579 ***
	(0.0183)	(0.0183)	(0.0183)	(0.0183)
L (t)		0.1288 ***	0.1273 ***	0.1008 ***
		(0.0381)	(0.0381)	(0.0388)
L (t-1)		-0.0011	-0.0011	-0.0011
		(0.0015)	(0.0015)	(0.0013)
(R&D / Sales) (t)		0.4222 ***	0.4326 ***	0.5141 ***
		(0.1620)	(0.1620)	(0.1616)
$(R\&D / Sales)^2$ (t)		-0.3003 **	-0.3092 **	-0.3723 **
		(0.1522)	(0.1522)	(0.1518)
log(K / L) (t)		0.0742 ***	0.0746 ***	0.0603 ***
		(0.0172)	(0.0172)	(0.0172)
Export rate (t)		0.1924 ***	0.1882 ***	0.1702 ***
		(0.0488)	(0.0488)	(0.0487)
Distance (t-1)			-0.0231	-0.0172
			(0.0231)	(0.0234)
Compet (t-1)				1.2986 **
				(0.6420)
$Compet^2$ (t-1)				-1.1065 **
				(0.4708)
mkt_share (t-1)				2.4826
				(1.8128)
mkt_share^2 (t-1)				-4.6384 **
				(2.2582)
mkt_rel (t-1)				1.1653 ***
				(0.3812)
mkt_rel^2 (t-1)				-0.8916 **
				(0.3796)
leader (t-1)				0.0084
				(0.1363)
σ (alpha)	0.5882 ***	0.5601 ***	0.5594 ***	0.5496 ***
	(0.0137)	(0.0136)	(0.0136)	(0.0135)

All firms : 9 374 firms, 48 520 observations, 2000-2013.

Full set of time dummies and initial value of variables not reported here.

Maximum likelihood estimation of panel probit model using Gauss-Hermite quadrature with 12 integration points. Asymptotic standard errors in parenthesis.

Estimates significant at 1% level : ***, at 5 % level : **, at 10% level :*.

Table 6b : Estimation results : Process Innovation

The technology gap has a negative effect on the probability to innovate in product. Thus an inefficient firm has lower incentives to innovate, which can broaden the technology gap. However the distance to technology frontier has no significant effect for process innovation. This result is rather counter-intuitive because the distance to the production frontier in the industry should imply an investment in production technology with an improvement in the process of production. But this variable can also capture the difference in total factor productivity within an industry. Therefore an industry with a heterogenous production technology and large difference in TFP reduce the incentives to innovate in product, while a more homogenous industry requires to introduce new product in order that firms remain competitive.

	Product			Process		
PRODUCT (t-1)	0.089	***	(0.006)	0.048	***	(0.006)
PROCESS (t-1)	0.060	***	(0.006)	0.124	***	(0.006)
emploi	0.025	*	(0.013)	0.035	***	(0.013)
emploi²	0.000		(0.000)	0.000		(0.000)
rd_intensity	0.273	***	(0.056)	0.178	***	(0.056)
rd_intensity²	-0.249	***	(0.052)	-0.129	**	(0.053)
lkl	0.014	**	(0.006)	0.021	***	(0.006)
export_rate	0.060	***	(0.017)	0.059	***	(0.017)
distance	-0.024	***	(0.008)	-0.006		(0.008)
Compet	0.831	***	(0.226)	0.449	**	(0.222)
Compet²	-0.879	***	(0.165)	-0.383	**	(0.163)
mkt_share	0.937		(0.639)	0.859		(0.627)
mkt_share²	-1.648	**	(0.781)	-1.606	**	(0.781)
mkt_rel	0.394	***	(0.133)	0.403	***	(0.132)
mkt_rel²	-0.412	***	(0.132)	-0.309	**	(0.131)
leader	0.085	*	(0.047)	0.003		(0.047)
PRODUCT (t=0)	0.136	***	(0.007)	0.066	***	(0.007)
PROCESS (t=0)	0.030	***	(0.007)	0.100	***	(0.007)

All firms : 9 374 firms, 48 520 observations, 2000-2013.

Panel Probit Estimates of Model (4). Asymptotic standard errors in parenthesis, significant at 1% level : ***, at 5 % level : **, at 10% level :*.

Table 7 : Average marginal effects – Estimation (4)

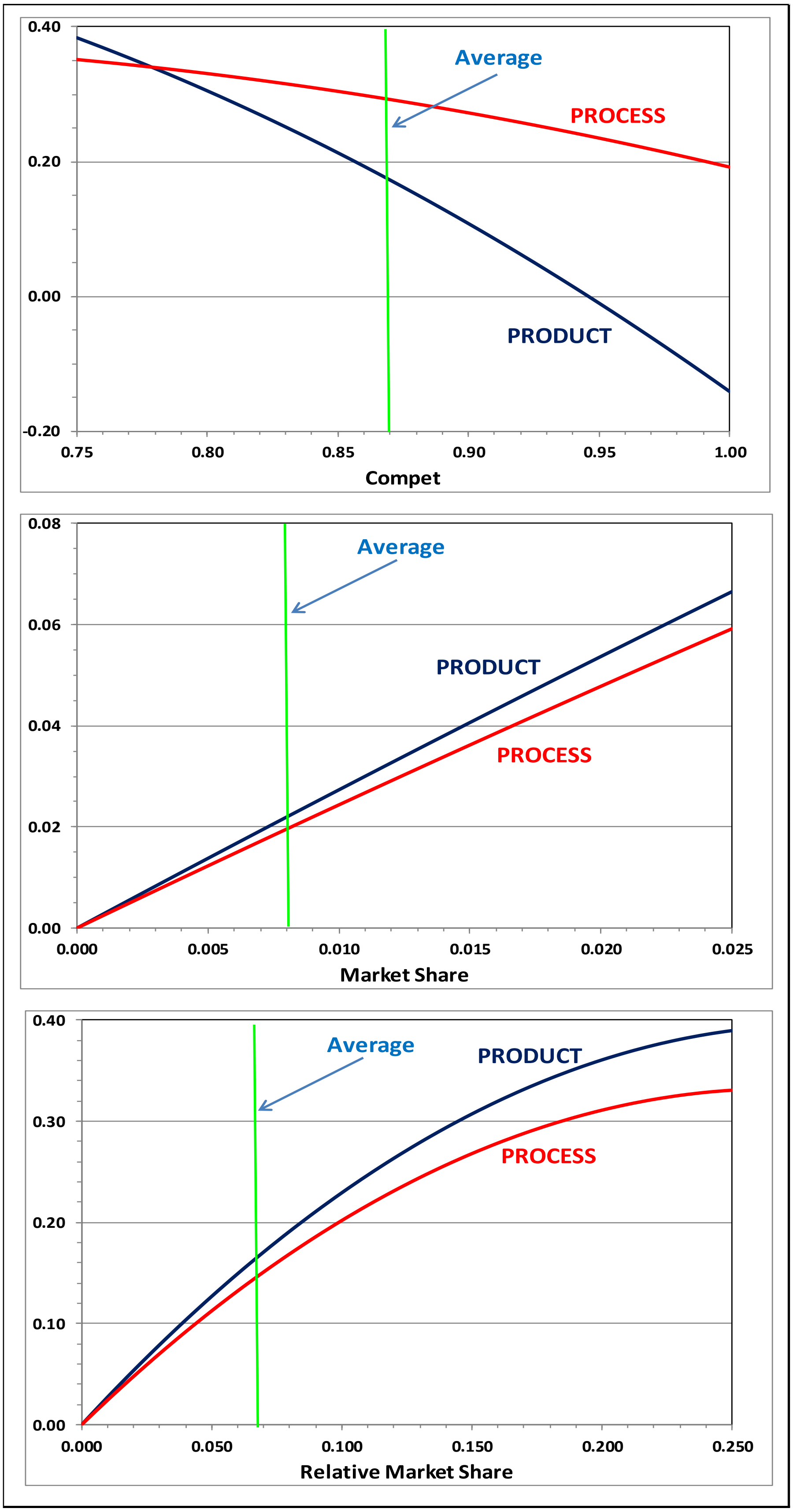
The competition measures (*Compet*, *mkt-share*, *mkt_relative*) have a significant effect on the product and process innovation. They are jointly significant and they exhibit also a significant quadratic pattern with an inverted U-shape like in ABBGH or in ACI. The effect of competition is larger for product innovation than for process innovation, while the market share (absolute or relative) seems to have a similar effect for both innovations.

But if the average marginal effect is considered, the maximum effect of competition is obtained for a competition measure of 0.47 for product innovation and 0.59 for process innovation. Nearly no firms are below these values. In Figure 3, the quadratic effect of the competition variable is plotted again the competition measure above 0.75 which represents approximately the first decile of its distribution. In fact more than 97% of observations are above the threshold of the maximum effect of competition. This means that the competition has a decreasing effect on the propensity to innovate for a large majority of the firm, even though this effect is convex. The Schumpetarian hypothesis is then confirmed with the data with a steeper effect for product innovation than for process innovation, the former will be more subject to the competition than the latter.

The absolute market share has the same inverted U-shape. But the level of this variable does not prove to be significant either for product than for process innovation because the market share can be correlated with the leader dummy, which is not really significant, or to the size of the firm. The plot of the average marginal effect of the market share in Figure 3, for 95% of observation where it is lower than 0.025, shows clearly that for most of the firms the effect is positive and quasi linear for reasonable value of the market share with again a small larger effect for product innovation than for process innovation. For these small values of market share, a rise by 1 percentage point in market share implies an increase by 2.5% in the probability to innovate in product or in process. The maximum marginal effects of of the market share are obtained for a market share by 34% and 38% respectively for product or process innovation, but it concerns less than 1% of observations in the sample. Thus a larger market share leads to a large propensity to innovate in product or in process. Within an industry, a larger market share leads to more innovations as in Blundell et al. (1999).

Finally the relative market has also a positive effect on the innovation with an inverted U-shape relationship with a maximum at 48% for product and 55% for process of the market share of the leader in the industry. After these maximum points, the propensity to innovate decreases, except for the leader which innovates in product. The propensity to innovate is higher for larger firms up to they have about half of the market share of the leader. Even though the average market share is 6.3%, even though the median is only 0.9%, it means that a large majority of firms (97%) are below the maximum level of the half of the leader market share. Therefore gaining market share for the followers increases the probability to innovate. But a too close market share relative to the leader (above 50% of its market share) decreases the propensity to innovate. For example, if a firm goes from a relative market share of 5% to 10%, the probability to innovate in product rises by 12% and by 10% for process innovations, which is a quite large effect for most of the firms. But a too close market share relative to the leader (above 50% of its market share) decreases the propensity to innovate. For example, a market share representing 80% of the leader, i.e. a market share equals 8% against 10% for the leader), reduces the probability to innovate by 30 percentage points for both product and process innovations.

An attempt to test the prediction of the ABBGH model where neck-and-neck firms with the same technological level support a larger effect of competition, relative to the heterogenous firms with unlevelled technology. As in their article, the technology gap is measured by the distance to the technology frontier. Then the competition measure (*Compet*) is interacted with the distance (all lagged once). Contrary to their paper, we reject the significance of the interacted effects in our estimation of a probit model on French firms' data. Thus the effect of the technology gap on the relationship of competition to innovation is not found in the French data. Moreover the relationship disappears entirely for process innovation.



<u>Figure 3 : Quadratic effects of competition measures</u>

5. Conclusions

This paper investigates the Schumpetarian hypothesis in the line of the paper by Aghion et al. (2005) or Askenazy et al. (2013). We use a panel data of French firms during the period 2000-2013, in order to measure the effects of the competition on the propensity to innovate in product or in process. The data allow distinguishing between product and process innovations because the firms report yearly if they introduce a product innovation, a process innovation or both.

In the French data, the innovation behavior of firms is persistent, either directly or indirectly with a cross effect between both types of innovation. This persistence is due to a state-dependence of innovation: that success in innovations breeds new successful innovation later, but also to unobserved firm's characteristics which are not fully captured by the control variables.

Several measures of competition are used in the estimation: a competition measure based on an industry Lerner index and an absolute or a relative market share. All these variables have an inverted U-shape effect on the propensity to innovate. But even though this convex shape is supported by the data, the reasonable range of values of these measures shows that competition have a negative effect on the propensity to innovate for most of firms. Moreover competition should have a larger effect on product innovations than on process innovations. Finally the French data does not support the last conclusion in ABBGH that the inverted-U shape is steeper when the firms operate with the same technology level.

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Appendix A : The sample

	Observations		Firms	
	Frequency	*Percent*	*Frequency*	*Percent*
Agricuture, Food, Drink	2 521	5.2%	463	4.9%
Machinery	10 067	20.7%	1 618	17.3%
Transport Materials	2 024	4.2%	311	3.3%
Other Manufactuing	14 128	29.1%	2 521	26.9%
Mines, Water, Energy	312	0.6%	69	0.7%
Building	652	1.3%	132	1.4%
MANUFACTURING	**29 704**	**61.2%**	**5 114**	**54.6%**
Trade, Transport and Logistics	2 890	6.0%	648	6.9%
Software, Communication and Press	7 284	15.0%	1 707	18.2%
Finance, Insurance	118	0.2%	39	0.4%
Housing activities	104	0.2%	29	0.3%
Business services	8 114	16.7%	1 775	18.9%
Other Services	306	0.6%	62	0.7%
SERVICES	**18 816**	**38.8%**	**4 260**	**45.4%**
TOTAL	**48 520**	**100.0%**	**9 374**	**100.0%**

Table A1 : Number of observation and firms by industry (2000 - 2013)

Average Employment	Observations		Firms	
	Frequency	*Percent*	*Frequency*	*Percent*
0 - 10	5 838	11.3%	1 629	17.4%
10 - 20	4 876	9.5%	1 190	12.7%
VERY SMALL FIRMS	**10 714**	**20.8%**	**2 819**	**30.1%**
20 - 50	9 376	18.2%	1 965	21.0%
50 - 100	9 821	19.1%	1 356	14.5%
100 - 250	9 149	17.8%	1 545	16.5%
SMALL AND MEDIUM SIZED FIRMS	**28 346**	**55.0%**	**4 866**	**51.9%**
250 - 500	5 368	10.4%	801	8.5%
500 - …	7 092	13.8%	888	9.5%
LARGE FIRMS	**12 460**	**24.2%**	**1 689**	**18.0%**
TOTAL	**51 520**	**100.0%**	**9 374**	**100.0%**

Table A2 : Number of observation and firms by size (2000 - 2013)

Appendix B : Results of Estimations

PRODUCT	(1)	(2)	(3)	(4)
Log likelihood	-28 201.6	-28 017.6	-27 993.8	-27 906.5
Wald Test	3 991.8	4 368.3	4 418.1	4 633.2
Prob > chi2	[0.0000]	[0.0000]	[0.0000]	[0.0000]
LR Test Firm Effects	1 451.9	1 303.4	1 287.2	1 201.5
Prob > chi2	[0.0000]	[0.0000]	[0.0000]	[0.0000]
PARAMETERS ESTIMATES				
Product (t-1)	0.2607 *** (0.0187)	0.2615 *** (0.0187)	0.2608 *** (0.0187)	0.2650 *** (0.0187)
Process (t-1)	0.1871 *** (0.0171)	0.1760 *** (0.0170)	0.1764 *** (0.0170)	0.1775 *** (0.0170)
L (t)		0.1102 *** (0.0314)	0.1086 *** (0.0313)	0.0750 * (0.0395)
L² (t)		-0.0004 (0.0004)	-0.0004 (0.0004)	-0.0005 (0.0013)
(R&D / Sales) (t)		0.6777 *** (0.1667)	0.7285 *** (0.1668)	0.8111 *** (0.1655)
(R&D / Sales)² (t)		-0.6483 *** (0.1560)	-0.6768 *** (0.1559)	-0.7401 *** (0.1548)
log(K / L) (t)		0.0627 *** (0.0177)	0.0634 *** (0.0177)	0.0428 ** (0.0177)
Export rate (t)		0.2187 *** (0.0501)	0.2073 *** (0.0500)	0.1777 *** (0.0497)
Distance (t-1)			-0.0810 *** (0.0218)	-0.0702 *** (0.0239)
Compet (t-1)				2.4691 *** (0.6717)
Compet² (t-1)				-2.6098 *** (0.4897)
mkt_share (t-1)				2.7823 (1.8987)
mkt_share² (t-1)				-4.8940 ** (2.3193)
mkt_rel (t-1)				1.1692 *** (0.3958)
mkt_rel² (t-1)				-1.2240 *** (0.3911)
leader (t-1)				0.2518 * (0.1384)
Constant	-1.1270 *** (0.0344)	-1.6763 *** (0.0932)	-1.5721 *** (0.0943)	-1.4751 *** (0.2474)
ln(σ²_alpha)	-0.9244 *** (0.0453)	-1.0172 *** (0.0468)	-1.0275 *** (0.0470)	-1.0932 *** (0.0481)
σ_alpha	0.6299 *** (0.0143)	0.6013 *** (0.0141)	0.5982 *** (0.0141)	0.5789 *** (0.0139)
TIME DUMMIES ESTIMATES				
year 2001	0.7796 *** (0.0400)	0.7872 *** (0.0401)	0.7875 *** (0.0401)	0.7943 *** (0.0401)
year 2002	0.4376 *** (0.0391)	0.4539 *** (0.0392)	0.4548 *** (0.0392)	0.4691 *** (0.0392)
year 2003	0.4516 *** (0.0381)	0.4722 *** (0.0382)	0.4738 *** (0.0382)	0.4999 *** (0.0383)
year 2004	0.5426 *** (0.0383)	0.5647 *** (0.0384)	0.5661 *** (0.0384)	0.5825 *** (0.0384)
year 2005	0.7049 *** (0.0390)	0.7238 *** (0.0391)	0.7271 *** (0.0391)	0.7277 *** (0.0391)
year 2006	0.3669 *** (0.0389)	0.3804 *** (0.0390)	0.3841 *** (0.0390)	0.3901 *** (0.0390)
year 2007	0.8761 *** (0.0402)	0.8845 *** (0.0403)	0.8881 *** (0.0403)	0.8905 *** (0.0402)
year 2008	0.9840 *** (0.0407)	0.9889 *** (0.0408)	0.9930 *** (0.0408)	0.9940 *** (0.0408)
year 2009	0.9597 *** (0.0403)	0.9648 *** (0.0404)	0.9867 *** (0.0407)	0.9445 *** (0.0405)
year 2010	0.8402 *** (0.0396)	0.8449 *** (0.0398)	0.8670 *** (0.0400)	0.6701 *** (0.0463)
year 2011	0.9117 *** (0.0395)	0.9174 *** (0.0396)	0.9411 *** (0.0398)	0.7557 *** (0.0462)
year 2012	1.1790 *** (0.0402)	1.1816 *** (0.0403)	1.2066 *** (0.0405)	1.0548 *** (0.0454)
year 2013	1.4200 *** (0.0429)	1.4141 *** (0.0430)	1.4378 *** (0.0432)	1.3013 *** (0.0470)
PARAMETERS ESTIMATES - INTIAL EFFECTS				
Product (t = 0)	0.4305 *** (0.0236)	0.4158 *** (0.0231)	0.4108 *** (0.0231)	0.4042 *** (0.0227)
Process (t = 0)	0.0976 *** (0.0227)	0.0865 *** (0.0222)	0.0856 *** (0.0222)	0.0905 *** (0.0218)
L (t = 0)		-0.0120 (0.0311)	-0.0142 (0.0310)	-0.0252 (0.0417)
L² (t = 0)		0.0000 (0.0004)	0.0000 (0.0004)	0.0003 (0.0015)
(R&D / Sales) (t = 0)		0.2321 (0.1712)	0.2528 (0.1711)	0.4109 ** (0.1705)
(R&D / Sales)² (t = 0)		-0.2284 (0.1625)	-0.2196 (0.1622)	-0.3618 ** (0.1613)
log(K / L) (t = 0)		-0.0281 (0.0176)	-0.0267 (0.0176)	-0.0264 (0.0175)
Export rate (t = 0)		0.2157 *** (0.0560)	0.2099 *** (0.0559)	0.1860 *** (0.0553)
distance (t = 0)			-0.0892 *** (0.0256)	-0.0472 * (0.0281)
Compet (t = 0)				-1.8711 ** (0.8345)
Compet² (t = 0)				1.9740 *** (0.5667)
mkt_share (t = 0)				-1.4756 (2.0707)
mkt_share² (t = 0)				3.6519 (2.5345)
mkt_rel (t = 0)				0.9688 ** (0.4398)
mkt_rel² (t = 0)				-1.2350 ** (0.5088)
leader (t = 0)				0.2048 (0.2280)

Standard errors in parenthesis. * : significant at 10% level, ** : significant at 10% level, *** : significant at 10% level,

<u>Table B1 : Estimation Results for Product Innovation (2000 - 2013)</u>

PROCESS	(1)		(2)		(3)		(4)	
Log likelihood	-28 742.9		-28 017.6		-28 548.6		-28 494.1	
Wald Test	4 012.2		4 368.3		4 435.4		4 567.8	
Prob > chi2	0.0000		0.0000		0.0000		0.0000	
LR Test Ind.Eff.	1 308.7		1 303.4		1 154.4		1 104.6	
Prob > chi2	0.0000		0.0000		0.0000		0.0000	
PARAMETERS ESTIMATES								
Product (t-1)	0.1542 ***	(0.0170)	0.2615 ***	(0.0187)	0.1411 ***	(0.0169)	0.1375 ***	(0.0169)
Process (t-1)	0.3533 ***	(0.0183)	0.1760 ***	(0.0170)	0.3554 ***	(0.0183)	0.3579 ***	(0.0183)
L (t)			0.1102 ***	(0.0314)	0.1280 ***	(0.0381)	0.1008 ***	(0.0388)
L (t-1)			-0.0004	(0.0004)	-0.0011	(0.0015)	-0.0011	(0.0013)
(R&D / Sales) (t)			0.6777 ***	(0.1667)	0.4432 ***	(0.1622)	0.5141 ***	(0.1616)
(R&D / Sales)² (t)			-0.6483 ***	(0.1560)	-0.3123 **	(0.1522)	-0.3723 **	(0.1518)
log(K / L) (t)			0.0627 ***	(0.0177)	0.0745 ***	(0.0172)	0.0603 ***	(0.0172)
Export rate (t)			0.2187 ***	(0.0501)	0.1874 ***	(0.0488)	0.1702 ***	(0.0487)
Distance (t-1)					-0.0343	(0.0213)	-0.0172	(0.0234)
Compet (t-1)							1.2986 **	(0.6420)
Compet² (t-1)							-1.1065 **	(0.4708)
mkt_share (t-1)							2.4826	(1.8128)
mkt_share² (t-1)							-4.6384 **	(2.2582)
mkt_rel (t-1)							1.1653 ***	(0.3812)
mkt_rel² (t-1)							-0.8916 **	(0.3796)
leader (t-1)							0.0084	(0.1363)
Constant	-1.3270 ***	(0.0354)	-1.6763 ***	(0.0932)	-1.8728 ***	(0.0921)	-2.2173 ***	(0.2395)
ln(σ²_alpha)	-1.0615 ***	(0.0466)	-1.0172 ***	(0.0468)	-1.1624 ***	(0.0485)	-1.1971 ***	(0.0493)
σ_alpha	0.5882 ***	(0.0137)	0.6013 ***	(0.0141)	0.5592 ***	(0.0136)	0.5496 ***	(0.0135)
TIME DUMMIES ESTIMATES								
year 2001	0.7434 ***	(0.0409)	0.7872 ***	(0.0401)	0.7487 ***	(0.0410)	0.7533 ***	(0.0410)
year 2002	0.4285 ***	(0.0402)	0.4539 ***	(0.0392)	0.4449 ***	(0.0403)	0.4517 ***	(0.0404)
year 2003	0.9954 ***	(0.0394)	0.4722 ***	(0.0382)	1.0176 ***	(0.0394)	1.0293 ***	(0.0395)
year 2004	1.0695 ***	(0.0399)	0.5647 ***	(0.0384)	1.0898 ***	(0.0400)	1.0983 ***	(0.0400)
year 2005	0.5887 ***	(0.0399)	0.7238 ***	(0.0391)	0.6064 ***	(0.0400)	0.6099 ***	(0.0400)
year 2006	0.8719 ***	(0.0400)	0.3804 ***	(0.0390)	0.8859 ***	(0.0401)	0.8893 ***	(0.0401)
year 2007	0.7968 ***	(0.0408)	0.8845 ***	(0.0403)	0.8027 ***	(0.0409)	0.8037 ***	(0.0408)
year 2008	0.8724 ***	(0.0409)	0.9889 ***	(0.0408)	0.8772 ***	(0.0410)	0.8781 ***	(0.0410)
year 2009	0.9732 ***	(0.0407)	0.9648 ***	(0.0404)	0.9848 ***	(0.0411)	0.9712 ***	(0.0410)
year 2010	0.8743 ***	(0.0401)	0.8449 ***	(0.0398)	0.8849 ***	(0.0405)	0.8317 ***	(0.0465)
year 2011	0.9436 ***	(0.0400)	0.9174 ***	(0.0396)	0.9546 ***	(0.0403)	0.9054 ***	(0.0463)
year 2012	1.1888 ***	(0.0402)	1.1816 ***	(0.0403)	1.1986 ***	(0.0405)	1.1582 ***	(0.0453)
year 2013	1.4281 ***	(0.0424)	1.4141 ***	(0.0430)	1.4279 ***	(0.0427)	1.3909 ***	(0.0466)
PARAMETERS ESTIMATES - INTIAL EFFECTS								
PRODUCT (t-1)	0.1918 ***	(0.0221)	0.4158 ***	(0.0231)	0.1899 ***	(0.0216)	0.1900 ***	(0.0215)
PROCESS (t-1)	0.3124 ***	(0.0223)	0.0865 ***	(0.0222)	0.2916 ***	(0.0218)	0.2887 ***	(0.0217)
emploi			-0.0120	(0.0311)	-0.0408	(0.0402)	-0.0514	(0.0409)
emploi2			0.0000	(0.0004)	0.0008	(0.0018)	0.0010	(0.0015)
rd_intensity			0.2321	(0.1712)	0.4888 ***	(0.1652)	0.6484 ***	(0.1658)
rd_intensity2			-0.2284	(0.1625)	-0.3302 **	(0.1568)	-0.4709 ***	(0.1570)
lkl			-0.0281	(0.0176)	-0.0362 **	(0.0170)	-0.0389 **	(0.0170)
export_rate			0.2157 ***	(0.0560)	0.1906 ***	(0.0541)	0.1702 ***	(0.0538)
distance					-0.0352	(0.0246)	-0.0112	(0.0272)
Compet							-0.1145	(0.7987)
Compet2							0.3226	(0.5437)
Compet * distance							-1.6189	(1.9781)
Compet2 * distance							3.5331	(2.4529)
mkt_rel							0.7485 *	(0.4212)
mkt_rel2							-1.2278 **	(0.4855)
leader							0.4279 **	(0.2152)

Standard errors in parenthesis. * : significant at 10% level, ** : significant at 10% level, *** : significant at 10% level,

<u>Table B2 : Estimation Results for Process Innovation (2000 - 2013)</u>