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Start-ups, firm growth and the consolidation of the French biotech industry

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Abstract Based on an original dataset, we analyze empirically the determinants of firm growth in the French biotech industry during two periods, 1996-1999 and 1999-2002. We have two main results. First, Gibrat's law is violated. The growth of annual turnover is influenced by the initial size of the firm. The effect is non-linear, negative for small firms. Second, location has a significant impact on growth. We use different sets of dummies to characterize location and different measures of firm growth. As a whole, our results point at Marseilles (and its region) and Nanterre (but not Paris and Evry) as favorable places for the growth of firms between 1999 and 2002. For the 1996-1999, the favorable places are Strasbourg (and Alsace) and Rhône-Alpes (Lyon/Grenoble). Our analysis thus suggests that the changes in the (notably legal) environment of French biotech firms that took place in 1999 had a drastic effect on the comparative advantages of locations for biotech firms.

Keywords Biotechnology, Industrial clustering, Firm growth.
JEL Codes L25, L65, R30.

1 Introduction

Despite the importance of the issue, the empirical literature on firms' growth in high tech sectors is quite small. Indeed, most of the literature on high-tech firms explores questions that are related to this one, but different. For example, Prevezer (1995) analyzes the growth of *clusters* of biotech firms, not of the firms themselves.[1] Since the growth of a cluster is measured by the number of firms entering the cluster each year, it is related to the creation of new firms

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[1] For other contributions along this line, see e.g. Baik and Folta (2001) and Swann, Prevezer and Stout (1998).

rather than to the growth of existing firms. In general, there is much more work on firms' creation than on firms' growth in high-tech sectors. These papers provide valuable insight for the analysis of firms' growth, but it is certainly recommendable to be cautious when extrapolating the results on creation to the analysis of growth. For example, Prevezer and Swann (1996) analyze both the creation and the growth of biotech firms (measured by employment) and show that the determinants of creation and growth are quite different. While the creation of biotech firms in a cluster is fostered by the level of employment in the science base and the firms in other biotech sectors, growth is promoted by the employment in the firms in the same biotech sector.[2] Furthermore, most of the studies exploring post-creation performances of individual firms explore dimensions of firms' performances other than the growth of turnover or employment. Aharonson et al. (2004), e.g., analyzes the impact of location on firms' inventiveness. Zucker, Darby and Armstrong (2002) analyzes the influence of the links between scientists and firms on firms' innovative performances in the biotech industry.[3] Gilbert, Audretsch and McDougall (2004) provides an extensive review of this (mainly managerial) literature. In this paper, we focus on the growth of firms' turnover. This is because what we are interested in is whether and how the biotech industry can bring products and services to the market and create value by selling them. There is no guarantee that results obtained for various measures of performance are valid when analyzing the growth of turnover. This being said, we recall the main results from previous work on the biotech industry.

Powell et al. (1996) and Baum et al. (2000) point at the role of alliances as determinants of the performances of biotech firms. Powell et al. (1996) show that alliances have a positive impact on the growth of biotech firms' employment. They see alliances as a major vehicle of knowledge flows and insist on the importance of firms' centrality in networks of learning. Niosi (2003) challenges this view in two ways. Firstly, he shows that there are other determinants of (fast) growth that are as crucial as alliances, namely access to venture capital and exports.[4] Secondly, he claims that alliances are not necessarily successes, in particular when they are formed too early or too late. He also insists on the necessity to distinguish between the many types of alliances that biotech firms can build (with universities, other biotech firms, big pharmas, ...). Audretsch and Feldman (2003) also underline the fact that biotech firms may well form alliances simply because of a lack of resources and that this may well not be

[2] This can be interpreted as a demand side effect: firms' growth benefits from sectorial (inter-industry) demand and information externalities which reduce search costs for users.

[3] They show that coauthorship between firms scientists and university scientists, in particular star scientists, increases the patenting performances of firms. See below the discussion of the role of science in firms' performances. The authors also analyze the impact of coauthorship on products and employment, but due to multicollinearity problems, the results are not reliable. The article includes historical perspectives on the industry and a review of the literature on science-firms links in the sector.

[4] Niosi (2003) considers Canadian firms. This is probably why exports (to the US market) are so important.

optimal in terms of the long term development of the industry.[5] They claim that internal growth, in particular the vertical integration of production stages in medical biotechs, may be a better way to follow. On the same point, Feldman and Ronzio (2001) report the results of a survey showing that 80% of the surveyed biotech firms would like to integrate vertically into manufacturing. They suggest that vertical integration will develop in the biotech sector and that the "virtual firm" model defended by Powell et al. (1996) may well be transitory.[6] There is another point on which divergent views expressed in the literature, namely the importance of geographic proximity in alliances between dedicated biotech firms and their big industrial clients, notably pharmaceutical firms. While Prevezer (2001) suggests that the difficulties of British biotech firms to form links with big local players explain part of the existing gap between the British and US industries, Zeller (2001) claims that it is not a problem for biotech firms specialized in research in the medical sector to form alliances with pharmaceutical firms around the world. The issue is in fact not whether collocation is important in industrial alliances, but whether it is more important in these alliances than in others. Prevezer and Swann (1996) point at the fact that biotech clusters formed around universities rather than around big industrial players, suggesting that these firms are not key elements of the environment for biotech firms. Audretsch and Feldman (2003) and Feldman (2003) claim that while this holds for the early stages of development of the industry, big firms may play a crucial role at later stages, because they are able to anchor a developing industry in a location.[7] For the period we consider, it is probably too early for anchor firms to play a significant role in the French biotech sector, even if this hypothesis clearly deserves attention and statistical testing.

Beside the possible role of local big industrial firms as anchor tenants, the literature has identified two key aspects of the local environment in high-tech industries. Biotech firms are strongly dependent on both basic science and venture or equity financing. Let us first review the knowledge issue, that is both the existence of a strong local science base and, more generally, the fact that firms enjoy knowledge spillovers. Since Jaffe et al. (1993), it is a broadly accepted view that knowledge spillovers are essentially local, at least at the early stages of development of the technology, because spatial proximity fosters the transfer and acquisition of tacit (and complex) knowledge. It is thus natural to assume that the existence of spillovers will attract firms to a given place and will favorably influence their posterior performances. In a seminal paper, Audretsch and Feldman (1996) show that the geographic concentration of innovation in

[5] Lerner et al. (2003) show that in periods in which biotech firms have difficulties to rise equity capital, they are more likely to fund R&D through alliances with major corporations. These alliances are significantly less successful than the alliances formed when public market financing is easy. The authors' interpretation of this result is that when public market financing is difficult, biotech firms cede more (in fact too many) control rights to the financing firm, which reduces the efficiency of the outcome (Aghion and Tirole (1994)).

[6] For early discussions of vertical integration in the biotech sector, see also Pisano (1990, 1991).

[7] On the anchor tenant hypothesis (in medical imaging, neural networks and signal processing), see also Agrawal and Cockburn (2003).

US industrial sectors is explained by the importance of knowledge spillovers in the sector, even after controlling for the concentration of production. Zucker and al. (1998a) confirms that the existence of a strong scientific base and more specifically the presence of star scientists explain both firms' location and their subsequent growth. Audretsch and Stephan (1996) examines whether the collocation of firms and scientists indicates that the firms indeed form links with *local* scientists. They show that it depends strongly on the role scientists play in the firm. When knowledge transfers are central in the relation, as is the case when scientists found firms, the propensity for the network to be local is substantially increased. Zucker et al. (1998b) also sheds some light on the mechanisms at work in localized knowledge spillovers. They consider Californian biotech firms and show that while publications by local star scientists formally linked to a firm increase this firm's employment growth (between 1989 and 1994), the publications by local stars not formally related to a firm don't impact on its growth. They conclude that in the biotech sector, knowledge diffuses through formal market relations rather than through the more informal diffusion process generally pointed at when dealing with knowledge spillovers.

As regards the dependence to financing, the literature suggests that the development of local venture capital is important, even if its impact on firms' growth is not clearly established. Powell et al. (2002) provide abundant illustration of the collocation of venture capital and biotech firms in the US. They also examine the evolution of the collocation pattern over time. However, they don't examine the impact of the presence of venture capital in the local environment on firms' performances. Stuart and Sorenson (2003) shows that VC and biotech firms' collocation fosters new firms' creation, but the local conditions that promote new venture creation differ from those that maximize the performance of recently established companies. Concerning the time to IPO, startups in close proximity to dense clusters of structurally equivalent high-technology firms perform worse than otherwise comparable organizations in less concentrated areas. This suggests the existence of congestion costs in dense clusters. The collocation of venture capital and biotech firms doesn't impact on the time to IPO.

In this paper, we explore the link between location and growth in the French biotech industry between 1996 and 2002, distinguishing between two subperiods, 1996-1999 and 1999-2002.[8] We estimate a baseline model in which we include only size and age variables. Based on these estimations, we select the model best suited for each of the two periods. A by-product of this analysis is that we test for Gibrat's law for French biotech firms. There is a huge literature on Gibrat's law and more generally on the link between size, age and growth. The classical empirical references are Evans (1987a, 1987b), Dunne, Roberts and Samuelson (1989) and Hall (1987). On the theoretical side, there are two main references, Pakes and Eriksson (1998) and Jovanovic (1982). See Sutton (1997) for an

[8] Globerman et al. (2005) examine the same issue for Canadian information technology firms between 1998 and 2001. They find that the distance to Toronto has an impact on the growth of firms' turnover, while locational dummy variables have no impact. They also analyze the survival of firms and find no impact of localization.

excellent survey on these issues. See also Geroski (1995). Since the publication of these surveys, the flow of papers on the topic continued and we don't intend to provide here a survey of this literature. To put it briefly, it seems well established that size and age have a negative influence on growth.[9] Quite interestingly for us, Almus and Nerlinger (2000) examine the link between size and growth for young firms belonging to technology intensive branches of the West German manufacturing sector between 1989 and 1994. Their results confirm the negative impact of size on growth. Furthermore, they find no significant difference in the impact of size on growth between technology intensive and non-technology intensive branches. This suggests that high-tech firms may be similar to more traditional firms in this regard.[10]

In order to capture the impact of location on growth, we then introduce dummy variables corresponding to locations in the models. We use three alternative sets of dummies. The first set corresponds to administrative regions. This is in line with the work on French firms by Autant-Bernard and al. (Autant-Bernard and al. (2003)) and several U.S. studies, using the state level as the unit of location (Audretsch and Feldman (1996), Prevezer (1995)).[11] This set of dummies is readily available and produces interesting results, but probably captures more than the local effects we want to focus on. There is a need to narrow the geographic scope of the areas if we want to approximate science districts. The second set of dummies is a first attempt to do that. We in fact characterize the firms based on their being or not in a urban unit in which a genopole is operating.[12] At least two studies report preliminary results (based on small number of firms) for firm growth and survival in and out science parks (Löfsten and Linderlöf (2002), Fergusson and Olofsson (2004)). The third set of dummies is more refined. We build clusters based on a hierarchical clustering analysis and retain 15 clusters.[13] The shape of clusters (in terms of geographic spread in particular) is coherent with the notion one can have of a science district as an agglomeration of science based firms, small or large, glued together

[9] There is also some work on the persistence of growth. Recently, Congming and Lee (2003) shows that sales growth of biotech firms over the 1995-1997 period is positively influenced by sales growth between 1993 and 1995. We don't test for such effects in this paper. Our primary focus in on the comparison of the two periods rather than on the persistence of growth from one period to the other.

[10] While there is abundant literature on the link between size and growth in manufacturing sectors, there are few studies on the link between size and growth in the services. In the only study of services sectors we know, Audretsch et al. (2002) validate Gibrat's law for a large sample of Dutch firms in the hospitality industries. It is an open question whether this result is valid for service firms operating in other sectors. In particular, some biotech firms provide research services to other firms, but given the difference between hospitality activities (hotels, ...) and R&D services, it seems reasonable not to draw any conclusions from Audretsch et al. (2002) for our purpose.

[11] For the USA, Zucker and al. (1998) use Functional Economic Areas as an alternative to states.

[12] Similarly, DeCarolis and Deed (1999), e.g., use Metropolitan Statistical Areas for the USA.

[13] Baik and Folta (2001) use a similar approach, although they are not very precise in the description of the methodology used to build the clusters. Audretsch and Stephan (1996) build geographic areas that are in general larger than a city but smaller than a state.

by knowledge flows. This approach is also in line with a recent study of industrial clustering of Canadian biotechnology firms (Aharonson and al. (2004)). It has the advantage not to rely on the assumption that each and every firm is in a cluster.

We combine these different approaches of location with two approaches of growth (in fact two baseline models): one in which we regress firms' growth on the previously listed explanatory variables and one in which we explain the probability that firms' experience fast growth in the period. We distinguish between two types of fast growing firms, gazelles and impalas. The estimations of these different models converge to a quite clear picture of the role of location in firms' growth in France over the 1996-2002 period.

The next section presents the context in which French biotech firms emerged and grew in the period. Section 3 presents the data we use to run our estimations. Section 4 presents the basic growth model. The estimations of this model are in section 5. Section 6 and 7 are devoted to fast growth models. Section 8 concludes the paper and suggests directions for future work.

2 The context of French biotech firms' development

The creation of Dedicated Biotech Firms has started in France in the 1980's.[14] The Law on innovation, enacted 1999 July 12th, also called the Allegre Act, introduced new possibilities of cooperation between the research world (research institutions, universities, public labs...) and the firms' world.[15] Public researchers are now given more incentives to participate to firms' creations, while public research laboratories and universities have created transfer and valorization structures (e.g. France Innovation Scientifique et Transfert for the CNRS), etc. Venture capital dedicated to biotechnology was created at the same time. In this section, we briefly develop these different aspects of the French biotechnology context.

2.1 The French biotech context in January 1999

At that time, the French public policy in favour of research and innovation is fragmented. This fragmentation is due to a multi-actor and multilevel public policy (Reiss, 2003). The so-called "Rapport Guillaume" (Guillaume (1998)) on the French innovation system had shown that the efficiency of the massive R&D

[14] For more details on the French biotechnology industry and policy profile, see Enzig (1999), Senker (2001) and Reiss (2003).

[15] Loi n°99-587 du 12 juillet 1999 sur l'innovation et la recherche, JOURNAL OFFICIEL DE LA REPUBLIQUE FRANCAISE, 13 juillet 1999, n°160, p.10396. Available (by 13/02/03) at: <http://www.adminet.com/jo/19990713/MENX9800171L.html>. See also Circulaire du 7 octobre 1999 relative à l'application de la loi n°99-587 du 12 juillet 1999 sur l'innovation et la recherche concernant les coopérations des personnels de recherche avec les entreprises. MENRT, p.15344-15350. Available (by 13/02/03) at: <http://www.recherche.gouv.fr/technologie/mesur/innojo.htm>.

budget effort made by different ministries was challenged by poor links between the public and private sectors. The definition of large research programmes was modified in the late 1990s : from a large firms orientation in the early 1990s to a start-up creation and SMEs focus in the late 1990s (Enzig (1999) ; Senker (2001)). No specific fund is dedicated to the biotech industry at that time. From 1994 to 1998, the venture capitalists increased their investments in France by 13% (see Table 22).

While the French biotechnology profile regarding knowledge base indicators (publications in biotechnology field) is comparable with that of other large countries like the UK or Germany, France is not a leading country regarding the commercialisation of science (number of biotech companies or patent applications) over the 1994-2000 period (Reiss, 2003). During the 1990s, the process of consolidation (mainly mergers) in agrochemical, pharmaceutical and seed companies transformed the industrial environment of the emergent biotechnology sector in France. 165 biotech firms were created between 1993 and 1999.

2.2 The evolution of the context since 1999

The Allegre Act introduced new possibilities of cooperation between the research world (e.g., research institutes, universities, public lab) and the industry.[16] From that time, the institutional and legal context was more favorable to firm creation in high tech sectors and to technological transfer from public to private. New structures dedicated to biotechnology were designed: 5 Research and Technological Innovation Networks (Réseaux de Recherche et d'Innovation Technologique) regrouping public and private actors related to biotechnology were created : GenHomme (2000, vegetal genomics and GMO) , Génoplante (1999, genomics and proteomics for the human being), Technologies pour la santé (2000, medical applications), and Alimentation références Europe (2001, food). They received 130,9 MF of public funds in 2000. The Centres Régionaux d'Innovation et de Transfert de Technologie (CRITT) were developed specifically for the SMEs. The CRITT Bio-Industries in Midi-Pyrénées is dedicated to Biotechnologies.

The Research Ministry has also participated, with regional and local authorities, to the emergence of Bio-incubators and Genopoles. Bio-incubators help founders at the initial stage of development of their biotech firms. The bio-incubators are : Paris Biotech, Eurasanté in Lille, the Genopole of Evry, Crealys in Lyon, Atlanpole in Nantes, Semia in Strasbourg, Emergys in Rennes, Busi in Auvergne, and the incubators in Nîmes and Franche-Comté. Genopoles

[16] The law is composed of four parts. The first part deals with the collaborations between public researchers and firms. Researchers may be allowed to temporarily leave their job in order to work in a firm (creation or not) that will valorize their work or to participate to that firm's capital or to belong to a firm's committee without leaving their job. The second part is dedicated to relationships between firms and public research. It completes the 1982 and 1984 laws, by creating structures more adapted to high tech SME's. In particular, incubators may be developed. The third part aims at developing a favorable tax policy. The fourth part concerns a specific legal structure for innovative firms. Further changes in the legal context were introduced by the 2001 Law of Finances.

have been selected by the Research Ministry for their activity in the field of the genome and post-genome present a large-scale biology project, an excellent campus for training and research, a structured project for research promotion, a high-level bioinformatics unit, a structured project for biotechnology company creation. The genopoles are located around Evry, Lille, Strasbourg, Montpellier, Toulouse, Marseilles-Nice, Lyon-Grenoble and Rennes-Nantes. Three sites in Paris - the Institut Pasteur, the Montagne Sainte Geneviève group of laboratories and the Center for Human Genomics of Paris V University - form the "Ile de France" region genopole, with Evry as its flagship site.[17]

Finally, ANVAR, the national agency for research valorization, has increased its support to SMEs. Since 1999, it has been authorized to directly invest in firms' capital. Bioam, a venture capital fund dedicated to early-stage financing of biotech companies, was created in 2000. This fund has facilitated the first stage of development of biotech firms. It participates to the growing activity of venture capital in the field (their investments have grown by 34% from 1999 to 2003, as compared to 13% from 1994 to 1998, biotech being the first industry of investment since 2000 ; see Table 22). In 2000, no IPO was realized in France, against 4 in the United-Kingdom and 8 in Germany. The financial market is not sufficient to support the growth of the French biotechnology industry.

The institutional and public research infrastructures evolution initiated by the law on innovation in 1999 has contributed to reinforce research valorization and firm creation in France. The interest for industrial property has also been enhanced among public researchers, with the possibility to get financial profit from their research results. Industrial applications have been encouraged by a higher accessibility of the laboratories to venture capitalists or to co-funding. The sale of technological services by laboratories has been encouraged too. The venture capitalists have invested more funds in biotech during the 2000s than the 1990s. Finally, whereas the national government was a key player during the 1990s, regional and local authorities have been growing in importance more recently, through their implication in bio-incubators and genopoles. Because of the very significant changes that took place in 1999, it seems relevant to split the 1996-2002 period into two sub-periods, before and after 1999.

3 Data description

3.1 The database

3.1.1 The identification of biotech firms

We build the list of French biotech firms from 3 elements: the list of the GAEL laboratory, which collects information on biotech firms since 1999, a list provided by the French Research Ministry, which has also been following the biotech

[17] For more information on genopoles, see E.M.B.O. (2003) and Ernst&Young (2003). These reports, as well as other elements of information, are available on the home page of the National Genopoles Network at http://rng.cnrg.fr/?id=&origin=&plt=&lang=en.

sector for several years, and the firms which reported in the 2000, 2001 or 2002 R&D surveys more than 30% of their R&D expenditures in the biotech field. Merging these 3 lists, we identify 709 firms which exist or have existed in the period 1996-2002 and for which we have information on size for at least one year.

3.1.2 The variables in the database

We collected individual financial data on the firms in the sample for the 1996-2002 period, mainly from the DIANE database. This database also provides the employment for each year, the date of creation and the address of the firm. If the firm has several plants, we localize it at the headquarter of the firm. We use location information at the "communal" level, which allows us to build variables based on more aggregated geographic levels.

3.2 The samples used in regressions

3.2.1 The two periods

As already explained, we distinguish in our sample two periods of three years: the 1996-1999 period (sample 1) and the 1999-2002 period (sample 2). To study the growth of firms we need the size of the firm (measured by annual turnover) at the beginning and at the end of each period. This reduces our samples to firms which exist at the beginning and the end of the period and for which we have size information for both years. In particular, we exclude from the sample those firms that existed at the beginning of the period, but didn't survive until the end of the period. This creates a sample selection bias that will be addressed in future work. This typically supposes to run type II Tobit models (see Wooldridge (2002)).

3.2.2 Restrictions of samples

Our database includes large multisectorial firms which growth probably doesn't significantly depend on their activity in the biotech sector. We exclude them from the sample when estimating the models.[18] A preliminary analysis of the list of firms ranked by descending turnover suggests to exclude from the two samples firms with more than 75 millions € of sales at the beginning of the period. Using this threshold leads us to exclude two large dedicated biotech firms that are subsidiaries of multinationals.

Table A shows that sample 2 is larger than sample 1. This reflects the increase in the number of biotech firms over the 1996-2002 period.

[18] However, because they can be attractive for other biotech firms and more generally generate externalities for other biotech firms, we keep them to build our clusters (see below).

3.3 The samples description

3.3.1 Size and age variables

Tables B and C show the distribution of the variables in the two samples. The age of firms is on average of 13 years, with 25 percent of firms older than 15 years. These are mainly firms which existed before the emergence of new generation biotechs and specialized in the biotech field afterwards. The distributions of the sales variables ($S_{i,t}$ and $S_{i,t'}$) are very similar in Period1 & period2. Considering growth, the median increases slightly between the first and the second period, from 33% to 38%. Fifty percent of firms increased their sales by more than 30% over each period. The distribution of growth rates has a very large variance. In particular, some firms have huge growth rates. Q90 is around 300% between 1996 and 1999 and the mean is even larger, at about 800%. It is probably due to some firms (potentially very small ones) experiencing enormous growth rates (possibly corresponding to modest absolute growth). For this reason, the median is a better statistic in this case.

3.3.2 location variables

The regions There are 26 administrative regions in France (22 in the metropolitan area). Table D shows the distribution of firms between regions in both samples. About 28% of French biotech firms were in Ile-de-France in the first period as compared to about 26% in the second period.[19] The weight of the first region is very important but decreases slowly. The second region is Rhône-Alpes with 11% of biotech firms in the first period, rising to 13.5% in the second period. Next in descending order, Alsace and PACA represent about 8% each of biotech firms.

The genopoles Genopoles are science parks with a label from the French Ministry of Research. The label was created in 1999. They are now in a number of eight. We build the genopole variable by considering the "urban units" (French concept of city) which are at the hearth of the genopole: Paris, Lyon/Grenoble, Marseilles/Nice, Lille, Strasbourg, Toulouse, Montpellier, Rennes/Nantes. This is a bit rough. Clusters (see below) are more refined measures of location.

All genopoles are in the first regions in number of biotech firms. Only two regions, Aquitaine and Auvergne, have no genopole, although they have a significant number of biotech firms.[20] The distribution of firms between genopoles in shown in table E.

The clusters We build 15 clusters by removing from the sample the communes with less than 10 biotech firms in a 20 kilometers distance, and by grouping the remaining communes into 15 classes. The classification is given

[19] Ile-de-France is approximately the urban area around Paris. It is by far the biggest French region in terms of economic importance and population.

[20] Auvergne has a so-called "biopole", the Clermont-Limagne science park, which didn't receive the genopole label.

by a hierarchical clustering analysis based on the flight kilometer distance between the firms. All firms are localized at the City Hall of the commune where they have their headquarters. There are three clusters in Ile-de-France: Paris, Evry and Nanterre. While the first two clusters correspond to clearly identified research institutions (see section 2), Nanterre appears probably more because many firms have their headquarters in this area, including the French subsidiaries of multinational firms. This should be kept in mind when analyzing the results presented below. The distribution of firms between clusters is shown in table F.

4 The basic model

In this section, we present the results of the estimation on our data of a basic model of firm growth in which we don't include location variables. In the following sections, we augment the model to include location variables. At this stage, we include only two explanatory variables in the model, namely the size and the age of the firm at the beginning of the period. These are well established determinants of firm growth that it is natural to include in this basic model. Let us first consider the following basic model:

$$\left(\log S_{i,t'} - \log S_{i,t}\right)/(t'-t) = \alpha + \beta \log S_{i,t} + \varepsilon_{i,t} \tag{1}$$

where t is the initial year and $t\prime$ is the final year of the period and $S_{i,t}$ is firm i's size at date t. This is a standard model of firm growth. It is derived from

$$S_{i,t'} = S_{i,t}\left[G_{i,t}\right]^{t'-t} e^{\eta_{i,t}} \tag{2}$$

where $G_{i,t}$ is the annual growth rate of firm i between year t and year $t\prime$. Taking logarithms leads to

$$\log S_{i,t'} = \log S_{i,t} + (t'-t)\log G_{i,t} + \eta_{i,t} \tag{3}$$

and

$$\left(\log S_{i,t'} - \log S_{i,t}\right)/(t'-t) = \log G_{i,t} + \varepsilon_{i,t} \tag{4}$$

where $\varepsilon_{i,t} = \frac{1}{t'-t}\eta_{i,t}$.

Finally, taking

$$G_{i,t} = e^{\alpha}\left(S_{i,t}\right)^{\beta} \tag{5}$$

leads to (1).

4.1 The 1999/2002 period

Table 1(1) presents the estimation of equation (1) for the 1999-2002 period and annual sales as a measure of size. Although the model explains only 5.5% of the variance of sales' growth, it is globally significant at 1%. The impact of initial size on growth is negative, significant at 1%. This means that Gibrat's law of proportional effect, which can be stated here as $\beta = 0$, is not verified for French biotech firms over the 1999-2002 period. Small firms grow faster than large firms over the period.

The rather low value of R^2 in this regression suggests that we should include more variables in the model. A first natural candidate is the age of the firm. So, we now assume that:

$$G_{i,t} = e^{\alpha} \left(S_{i,t}\right)^{\beta} \left(A_{i,t}\right)^{\gamma} \tag{6}$$

where $A_{i,t}$ is firm i's age at date t, defined as the difference between t and the year of creation of the firm. This leads to:

$$\left(\log S_{i,t'} - \log S_{i,t}\right)/(t' - t) = \alpha + \beta \log S_{i,t} + \gamma \log A_{i,t} + \varepsilon_{i,t} \tag{7}$$

As can be seen from table 1(2), the inclusion of age improves the fit of the model for the 1999-2002 period. Age is significant at 1%, size at 5%, with a negative impact of age, which is not surprising in view of the literature.

There is another fruitful way to extend the model. Indeed, the scatter plots suggest that the link between initial sales and their subsequent growth is non-linear, with a more negative slope for small firms than for larger ones. To put it differently, it seems that the negative impact of size on growth is stronger for small firms. This is reminiscent of a result found by Hart and Oulton (1996). An estimation of (1) on the firms of the sales quartile of our sample (not reported here) confirms this. This leads us to introduce in the model powers of the size variable as explanatory variables. It turns out that a second degree polynomial provides a much better fit than the basic model. Table 2(1) reports the estimation of

$$\left(\log S_{i,t'} - \log S_{i,t}\right)/(t' - t) = \alpha + \beta_1 \log S_{i,t} + \beta_2 \left(\log S_{i,t}\right)^2 + \varepsilon_{i,t} \tag{8}$$

for the 1999-2002 period. In table 2(2), we report the estimation of the extension of this model that includes age as an explanatory variable, namely:

$$\left(\log S_{i,t'} - \log S_{i,t}\right)/(t' - t) = \alpha + \beta_1 \log S_{i,t} + \beta_2 \left(\log S_{i,t}\right)^2 + \gamma \log A_{i,t} + \varepsilon_{i,t} \tag{9}$$

Introducing the age in the regression improves the fit and doesn't induce dramatic changes in the values of the parameters or in their significance. In both models, logSales exhibits a negative coefficient that is much stronger that in the previous estimations. The square variable is significant, with a positive impact. We adopt the specification in (9) in the next sections for the 1999/2002 period.

4.2 The 1996/1999 period

Estimating equation (1) for the 1996-1999 period confirms the violation of Gibrat's law (table 3(1)). Note that the effect of size on growth is stronger (in absolute value) for this period and that the model exhibits a much better fit (as measured by R^2). However, table 3(2) shows that for the growth of sales between 1996-1999, age is not significant, even at 10%. So, while the violation of Gibrat's law is clear, it seems not to be pertinent to include age as an explanatory variable in the model for this period.

As regards the introduction of powers of the log of sales, a third degree polynomial clearly outperforms the second degree polynomial for the 1996-1999 period. Table 4 presents the estimation of

$$(\log S_{i,t'} - \log S_{i,t})/(t'-t) = \alpha + \beta_1 \log S_{i,t} + \beta_2 (\log S_{i,t})^2 + \beta_3 (\log S_{i,t})^3 + \varepsilon_{i,t} \tag{10}$$

and

$$(\log S_{i,t'} - \log S_{i,t})/(t'-t) = \alpha + \beta_1 \log S_{i,t} + \beta_2 (\log S_{i,t})^2 + \beta_3 (\log S_{i,t})^3 + \gamma \log A_{i,t} + \varepsilon_{i,t} \tag{11}$$

Size is a more decisive determinant of growth on this period than on the 1999/2002 period. Including age in the model doesn't seem to be pertinent. So, we use mainly equation (10) as a basis in the next sections for the 1996/1999 period.

5 The impact of location on growth

5.1 The 1999/2002 period

5.1.1 Administrative regions

A very simple way to introduce location in the model is to include dummy variables corresponding to the administrative region in which the firm is located. There are 22 metropolitan regions in France, but only 12 of these have a significant number of biotech firms (that is, at least ten firms in the sample).[21] So, we consider that in these 12 regions, firms may benefit from spill-overs while in the 10 other regions they don't. However, we include only 11 regional dummies in the model, excluding reg31(Nord-Pas-de-Calais) for which the number of firms in the sample used to estimate the model is too low.[22] Note that in 9 regions there is a genopole.[23] We estimate an extension of (9) including the

[21] This threshold, although arbitrary, seems reasonable. Baik and Folta (2001) use the same threshold, introducing a distinction between minor clusters (less than 20 firms) and major ones.

[22] We include only these dummy variables for which at least 10 observations take the value "1". Table D shows that this is the case for reg31, but we include age in the model and we don't know the age of one of the firms located in Nord-Pas-de-Calais.

[23] One of the 8 genopoles covers two regions, Bretagne and Pays-de-la-Loire.

dummy variables. Table 5 provides the results of this estimation. It turns out that for the 1999-2002 period, only one dummy variable (reg93) is significant, at a 5% level (p-value equal to 0.0106), with a positive effect, while others have rather large p-values. This dummy corresponds to Provence-Alpes-Côte-d'Azur, a region in southern France in which a genopole is functioning, mainly around Marseilles and Nice-Sophia-Antipolis.

Regional dummy variables are very rough measures of locational effects and are probably a poor approximation for science districts. The type of externalities intervening at the regional scale may be quite different from the knowledge externalities emphasized in the analysis of science districts. We estimated the models with more sophisticated indicators of location.

5.1.2 Genopoles

In a first attempt to capture science districts, we build dummy variables based on the fact that the firm is located in a urban area that is part of a genopole or not. We estimated a model including the dummy variables corresponding to 5 genopoles: Paris, Lyon/Grenoble, Marseilles/Nice, Strasbourg and Toulouse. There were to few firms in the other 3 genopoles in our sample to include the corresponding dummies in the model. For the 1999/2002 period, we found no significant influence of these variables on growth.[24] In particular, while Provence-Alpes-Côte-d'Azur was significant as a region, the Marseilles/Nice genopole is not. Either the forces at work in PACA are not localized (in Marseilles and/or Nice) or they are and our variable doesn't allow us to show it. The next subsection suggests that we are in the second situation.

5.1.3 Clusters

It turns out that the models in which location is described by cluster dummies provide the most interesting results. Table 6(2) shows that being located in Marseilles (cl11) has a positive, significant (at a 10% level) impact on growth. The effects observed at a regional level persist at the local (cluster) level. Table 6(1) shows that, removing age from the regression, Nanterre (cl1) and Toulouse (cl6) have a significant impact (at a 10% level), this impact being negative in the case of Toulouse. Since these effects vanish when we include age in the model (which improves the performances of the model), they probably reflect mainly the distribution of firms' ages in these two areas. We thus retain mainly table 6(2) and the Marseilles effect for this period.

5.2 The 1996/1999 period

5.2.1 Administrative regions

Between 1996 and 1999 (table 7), Provence-Alpes-Côte-d'Azur is not significant, Rhône-Alpes is (at a 1% level) and, at a 5% level, Alsace is also. The difference between the two periods is very clear. Note that the creation of genopoles

[24] The estimates are not reported here.

started in 1999, so that our results suggest that the creation of genopoles, and more generally the modification of the environment in which biotech firms were created and grew due to the so-called "Allegre" law, radically changed the relative performances of regions in terms of their ability to provide biotech firms with an environment favorable to their growth.

5.2.2 Genopoles

For the 1996/1999 period (table 8), Lyon/Grenoble (gen2) is significant at a 10% level which suggests that part of the effects associated with being located in Rhône-Alpes during this period are associated with being located either in Lyon or in Grenoble.[25]

5.2.3 Clusters

Table 9(1) presents the results for the 1996/1999 period. Here, the only significant cluster dummy is Paris (cl3), with a negative impact (significant at a 10% level) that is not due to the age distribution of firms in this area, as can be checked in table 9(2). In the "region" model, Ile-de-France has no impact on growth. It must be kept in mind that Ile-de-France includes 3 clusters, namely Nanterre, Evry and Paris. Distinguishing these three places is one of the good things in the "cluster" model. To the contrary, Alsace as a region is significant, but Strasbourg, as a cluster, is not.[26]

Including age in the regression, Lyon becomes significant. This is in line with the fact that Rhône-Alpes has a positive impact on growth (see table 7), but including age doesn't improve the performances of the model, so we retain mainly the Paris (negative) effect. One interpretation of this negative effect is that firms located in Paris suffer from diseconomies of agglomeration to be linked to high levels of congestion costs, strong local competition for localized inputs and knowledge expropriation. In other words, the cluster would be in the declining phase of its life cycle (see Pouder and Saint John (1996) and Baik and Folta (2001)). This interpretation seems implausible for two reasons. Firstly, Baik and Folta (2001) find that U.S. biotech clusters entered the decline phase after at least 20 years and the development of the French biotech industry dates back only to the 80's. One should then assume that this cluster entered the declining phase particularly fast. Secondly, and more importantly, there is no negative effect of being located in Paris in the estimates on the next period (1999/2002), which clearly challenges the "decline" hypothesis.

[25] Including age in the regression makes Lyon/Grenoble significant at a 5% level and Strasbourg (gen5) at a 10%. We don't report the estimation here, both to be in line with the other sections and, more importantly, because including age in the regression doesn't improve the fit. Recall however that Alsace was also found to be significant in the "region" analysis.

[26] In fact, Strasbourg has a positive, significant impact on the growth between 1996 and 1999 in models in which logSales^3 is not included, regardless of the fact that logAge is included or not. It is significant at 10% in the model without age and at 5% in the model with age. However, including the third degree term clearly improves the performances of the model, so we don't present these estimates.

5.3 Conclusion

Switching from the "region" model to the "cluster" model induces quite important changes in the results. There is however one result that is robust to this change in explanatory variables. Biotech firms grew more in PACA and/or Marseilles than in other locations between 1999 and 2002. Note that the amplitude of the effect is approximately the same in the "region" and the "cluster" models. Furthermore, the "cluster" model allows us to distinguish between different areas within Ile-de-France and show that Paris is a location in which, for the period 1996/1999, biotech firms grew slower than elsewhere.

6 The determinants of rapid growth

In this section, we use a different approach of the determinants of growth in general and the role of location in growth in particular.

6.1 The gazelle model

This section presents the rapid growth model. We distinguish between two types of firms, those that experience a rapid growth over the period (at least 50%) and the others. Fast growers are commonly named "gazelles" in the literature, which refers to the fact that these animals run very fast. We build a dummy variable, that is equal to one is the firm is a gazelle and zero otherwise, and put it in a logit model. The dummy variable is defined as follows:

$$y_i = \begin{cases} 1 & if \quad \frac{S_{i,t'} - S_{i,t}}{S_{i,t}} > 0.5 \\ 0 & otherwise \end{cases} \tag{12}$$

We then estimate the following equation:

$$P(y_i = 1 \,|\mathbf{x}_i\,) = \Lambda\left(\mathbf{x}_i'\boldsymbol{\beta}\right) \tag{13}$$

where Λ is the cdf of the standard logistic distribution, $\mathbf{x}_i$ is the vector of explanatory variables (for observation i) and $\boldsymbol{\beta}$ is the vector of parameters of the model. As for the study of growth, we take as explanatory variables the log of sales (and powers of the log of sales), the log of age and locational dummy variables (regions, genopoles, clusters). It turns out that introducing age in the regression improves the fit of the model, as would indeed the introduction of any variable, but size is no more significant, whereas it is significant at a 1% level when age is not included in the model. As regards powers of the size variable, the estimations clearly indicate that they should not be included in the model. We thus adopt a specification of the model with only size and locational variables both for the 1996-1999 and the 1999-2002 period. Tables 10 and 11 present the estimates for the basic model including only size as an explanatory variable.

6.2 The 1999/2002 period

6.2.1 Administrative regions

As in the growth case, location in the model is introduced by dummy variables corresponding to the administrative region in which the firm is located. We consider only the twelve regions where at least ten firms from the sample are present. Table 12 provides the estimates. It turns out that for the 1999-2002 period, two dummy variables, reg91 and reg93, are significant at a 5 % level. One dummy variable, reg73, is significant at a 10% level. The dummy reg93 corresponds to Provence-Alpes-Côte d'Azur and was already significant in the growth model. The dummy reg91 corresponds to Languedoc-Roussillon, in which a genopole (Montpellier) is functioning since 2001. The location in Languedoc-Roussillon was not significant in the growth model. Similarly, Midi-Pyrénées (reg73) was not significant in the growth model. While PACA is a place where firms both growth more and have a higher probability to experience fast growth, being located in Languedoc-Roussillon or in Midi-Pyrénées has an impact only on the probability of fast growth, while growth rates are not significantly larger than elsewhere.

6.2.2 Genopoles

Table 13 shows that there is only one out of our five genopole dummy variables that is significant. Being located in either Marseilles or Nice (in fact in the urban area of one of these two cities) has a positive, significant (at 5%) impact on the probability of fast growth. It has no significant impact on growth. While Midi-Pyrénées has a positive impact on the probability of fast growth, being located in Toulouse (gen6) is not significant. We cannot test the effect of being located in Montpellier because there are too few firms in the Montpellier urban area.

6.2.3 Clusters

Table 14 shows the estimates for the model including cluster dummies. Being located in Nanterre (Cl1) has a positive, significant impact on rapid growth at a 1 % level, while being located in Marseilles has a positive, significant impact at a 10 % level. The effects associated to Marseilles/PACA observed at the regional and the genopole levels persist at the cluster level. Recall also the Marseilles (as a cluster) has a positive impact on growth over this period. Furthermore, because we distinguish three clusters in Ile-de-France, Nanterre can appear as significant while Ile-de-France, Paris (cl3 & gen1) and Evry (cl5) do not.

6.3 The 1996/1999 period

6.3.1 Administrative regions

Between 1996 and 1999 (see table 15), Alsace is the only region with a significant impact on grow (at a 10 % level). Firms in this region had a higher probability to experience fast growth. This confirms the results of the growth models for this period. This is all the more the case as Rhône-Alpes, also it is not significant at a 10% level, has a p-value very close to 10.

6.3.2 Genopoles

No genopole has a significant influence on rapid growth. While Lyon/Grenoble has an impact on growth, it has no impact on rapid growth. We don't report the estimates of this model.

6.3.3 Clusters

No significant cluster variable. We don't report the estimates of this model.

7 Impalas

In the previous section, we analyze the determinants of the probability that a firm is a gazelle over the period. There are many species of gazelles with quite different characteristics. In particular, they differ by their size. For example, impalas are twice as big as springboks. In what follows, we use the term "impala" to describe big fast-growers, while springboks will denote small fast-growing firms. In the previous section, we don't distinguish between impalas and springboks. In this section, we focus on impalas. This is motivated by the simple fact that a 50% growth of a firm with ten thousands euros of turnover has very different consequences as the same growth rate for a firm with ten millions euros of turnover. In order to identify impalas, we modify the definition of the endogenous variable in (13) as follows:

$$y_i = \begin{cases} 1 & if \quad \frac{S_{i,t'}-S_{i,t}}{S_{i,t}} S_{i,t'} > Q_{75} \\ 0 & otherwise \end{cases} \tag{14}$$

where Q_{75} is the third quartile of the distribution of $\frac{S_{i,t'}-S_{i,t}}{S_{i,t}} S_{i,t'}$. This definition of impalas is based on the Birch Index, a combined measure of absolute and rapid growth. The Birch index is commonly used when studying fast-growing firms (Almus (2002)). Note that impalas are not necessarily gazelles as defined by (12).We then run estimations of the same type of models as in the previous section, with the difference that we include the squared log of size and the log of age as explanatory variables. The reason for this choice is that these models provide a much better fit than the model with only the log of size.[27] The rest of the section is devoted to the presentation of these estimates.

[27] Alternatively, explaining rapid growth in Canadian biotechnology firms, Niosi defines rapid-growth firms as firms that have grown of 50% and over of total employment and/or sales between 1994-1998 and that have crossed the threshold of 25 employees and/or 2 million dollars in sales (Niosi(2000,2003)).

7.1 The 1999/2002 period

7.1.1 Administrative regions

Two regional dummies have a positive impact significant at 1% (see table 16). These are PACA and Ile-de-France. While PACA is also significant in the gazelle model, Ile-de-France is not. This suggests that being located in Ile-de-France is positive for the (fast) growth of relatively big firms, this effect being diluted in the gazelle model because small firms don't experience fast growth with a higher probability in Ile-de-France. Furthermore, at 10%, Aquitaine has a positive impact on the probability to be an impala. Aquitaine has no impact in the gazelle model. Conversely, Midi-Pyrénées and Languedoc-Roussillon, which have an impact in the gazelle model, are not significant in the impala model.

7.1.2 Genopoles

The genopoles model confirms the significance of IdF in the impala model (see table 17). Paris is the only genopole dummy that is significant. Interestingly, Marseilles-Nice (gen3) is not, while it is in the gazelle model. This result suggests that Marseilles may well be a good place for springboks and Paris a good place for impalas.

7.1.3 Clusters

The clusters model indicates that it is in fact Nanterre within Ile-de-France that is favorable to the growth of impalas (see table 18). Recall that it is also the result obtained in the gazelle model. As for genopoles, Marseilles is not significant in the impala model, while it is in the gazelle model. Note however that the p-value associated to Marseilles is very close to 10%.

7.2 The 1996/1999 period

We don't present separately the three models because they provide essentially the same message (see tables 19 to 21). Two places increased the probability to be an impala in this period, Rhône-Alpes (the region, the Lyon-Grenoble genopole and the Lyon cluster) and Alsace (region, Strasbourg genopole, Strasbourg cluster). This confirms the results obtained from the growth and the gazelle models. Furthermore, genopoles and clusters are significant as well as regional dummies, while only the last are significant in gazelle models. This suggests that the role of the local environment in the growth of gazelles is the same for impalas and springboks over this period. This is a difference with the 1999/2002 period.

8 Conclusion

The analyses presented here lead to two main conclusions. Firstly, location matters in the French biotech industry. More precisely, it has a significant impact on firms' growth over the two periods considered in this paper. An interesting aspect of our results is that the locations that appear to be favorable are different before and after 1999. Alsace and Rhône-Alpes are better places than others before 1999. Concerning Alsace, we can relate this to the fact that Alsace is linked to the Biovalley Bioregio created in Germany in 1996 that received a significant amount of money between 1996 and 1999, while over the same period, there was no comparable program in France.[28] After 1999, it is clearly Marseilles (and its region) and Nanterre (and Ile-de-France, but it is less clear (see below)) that are better places for biotech firms to grow. We suspect that this evolution is related to the emergence of new structures and institutions to support biotech firms (incubators, genopoles, ...). Our results suggest that Marseilles was particularly successful in the development of an environment favorable to the growth of biotech firms, while being located in Nanterre increases more specifically the probability of fast growth. However, since we don't characterize locations by variables (other than dummy variables), it is not possible to say what aspect of a given location was favorable to firms' growth. Introducing variables characterizing the local environment is the next step. We use different concepts to capture location, one of which is the "cluster" level. Looking at clusters has the advantage to distinguish between different places in Ile-de-France. Nanterre turns out to be a favorable location after 1999 , while Paris and Evry don't. Because of the "headquarters" effect discussed in section 3, it is not clear what sort of mechanisms explain the effect of being located in Nanterre on growth. This point will be further examined in future work. An interesting point to note is that Nanterre is not significant for the 1996-1999 period. So, if Nanterre is significant because of a headquarters effect, which still has to be examined, it remains to understand why this effect didn't play for the first period considered in this paper. Our second main conclusion is that size also matters. In violation of Gibrat's law, the initial size of firms has a (non-linear, negative for small firms) impact on their subsequent growth. This is a stylized fact that is broadly documented in the literature. It is interesting to see that size explains a much larger part of firms' growth before 1999 than after. Our results are not very sensitive to the specification of the model. Regressions explaining the rate of growth and logit models explaining the probability of fast growth lead to roughly the same results. The most notable evolution is between gazelle and impala models, Ile-de-France emerging only in the second type of models.

[28] For more details about public support to biotechs in Germany, see Giesecke (2000), Krauss and Stahlecker (2001), Prevezer (2001) and Zeller (2001).

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Table A: Firms under 75M€ of sales at the beginning of the period

	1996-1999 (Sample 1)	1999-2002 (Sample 2)
Number of firms	314	393
$S_{i,t} > 0$	300	375
$S_{i,t} > 0$ & $S_{i,t'} > 0$	296	368

Notations: $S_{i,t}$ is firms i's sales at time t (beginning of the period) and $S_{i,t'}$ firm i's sales at time t' (end of the period).

Table B: Distribution of age in the samples

	1996-1999 (Sample 1)			1999-2002 (Sample 2)		
	All	$S_{i,t} > 0$	$S_{i,t} > 0$ & $S_{i,t'} > 0$	All	$S_{i,t} > 0$	$S_{i,t} > 0$ & $S_{i,t'} > 0$
Number of firms	314	300	296	393	375	368
Age at time t (years)						
Mean	13.3	13.4	13.6	12.7	13.0	13.2
Q10	2	2	2	1	1	1
Q25	4	4	4	4	4	4
Q50	7	7	7	8	8	8
Q75	16	16	16.5	15	15	15
Q90	35	35	35	27	27	28

Table C: Distribution of size variables in the samples

	1996-1999 (Sample 1)			1999-2002 (Sample 2)		
	All	$S_{i,t} > 0$	$S_{i,t} > 0$ & $S_{i,t'} > 0$	All	$S_{i,t} > 0$	$S_{i,t} > 0$ & $S_{i,t'} > 0$
Number of firms	314	300	296	393	375	368
$S_{i,t}$ **(M€)**						
Mean	6.6	6.9	7.0	6.4	6.7	6.8
Q10	0.06	0.10	0.11	0.05	0.10	0.10
Q25	0.3	0.3	0.4	0.3	0.3	0.4
Q50	1.3	1.4	1.5	1.2	1.5	1.5
Q75	5.9	6.9	7.0	6.2	6.5	6.6
Q90	18.1	18.2	18.3	19.0	20.2	20.3
$S_{i,t'}$ **(M€)**						
Mean	12.8	11.9	12.0	9.9	10.3	10.6
Q10	0.14	0.19	0.21	0.07	0.12	0.15
Q25	0.5	0.6	0.6	0.4	0.5	0.5
Q50	2.0	2.3	2.3	1.9	2.1	2.3
Q75	10.2	10.3	10.4	8.7	9.1	9.2
Q90	25.9	26.2	26.5	27.6	29.8	30.0
$(S_{i,t'} - S_{i,t})/S_{i,t}$						
Mean		7.78	7.9		1.41	1.45
Q10		-0.24	-0.20		-0.36	-0.28
Q25		0.07	0.07		0.06	0.08
Q50		0.33	0.34		0.38	0.40
Q75		0.90	0.93		0.96	0.99
Q90		2.90	2.92		1.94	1.95

Table D: Distribution of firms between regions

	Variable	1996-1999 (Sample 1)		
		All	$S_{i,t} > 0$	$S_{i,t} > 0$ & $S_{i,t'} > 0$
Number of firms		314	300	296
Ile-de-France	reg11	87	83	82
Rhône-Alpes	reg82	35	32	31
Alsace	reg42	24	24	24
PACA	reg93	25	23	23
Aquitaine	reg72	19	19	19
Bretagne	reg53	17	17	17
Midi-Pyrénées	reg73	17	16	16
Pays-de-la-Loire	reg52	15	15	15
Auvergne	reg83	11	9	9
Languedoc-Roussillon	reg91	9	9	9
Nord-Pas-de-Calais	reg31	9	9	7
Centre	reg24	8	8	8
Other regions		38	36	36

	Variable	1999-2002 (Sample 2)		
		All	$S_{i,t} > 0$	$S_{i,t} > 0$ & $S_{i,t'} > 0$
Number of firms		393	375	368
Ile-de-France	reg11	101	95	89
Rhône-Alpes	reg82	53	50	50
Alsace	reg42	29	28	28
PACA	reg93	31	31	31
Aquitaine	reg72	20	19	19
Bretagne	reg53	22	21	21
Midi-Pyrénées	reg73	19	18	18
Pays-de-la-Loire	reg52	20	20	20
Auvergne	reg83	18	17	17
Languedoc-Roussillon	reg91	15	14	14
Nord-Pas-de-Calais	reg31	12	10	10
Centre	reg24	12	12	11
Other regions		41	40	40

Table E: Distribution of firms between genopoles

	Variable	1996-1999 (Sample 1)		
		All	$S_{i,t} > 0$	$S_{i,t} > 0$ & $S_{i,t'} > 0$
Number of firms		314	300	296
Paris	gen1	79	75	74
Lyon/Grenoble	gen2	28	25	24
Marseilles/Nice	gen3	16	14	14
Strasbourg	gen5	14	14	14
Toulouse	gen6	12	11	11
Rennes/Nantes	gen8	7	7	7
Lille	gen4	5	5	3
Montpellier	gen7	2	2	2
Not in genopole		151	147	147
	Variable	1999-2002 (Sample 2)		
		All	$S_{i,t} > 0$	$S_{i,t} > 0$ & $S_{i,t'} > 0$
Number of firms		393	375	368
Paris	gen1	93	87	81
Lyon/Grenoble	gen2	43	40	40
Marseilles/Nice	gen3	23	23	23
Strasbourg	gen5	18	17	17
Toulouse	gen6	15	14	14
Rennes/Nantes	gen8	10	10	10
Lille	gen4	6	4	4
Montpellier	gen7	5	4	4
Not in genopole		180	176	175

Table F: Distribution of firms between clusters

	Variable	1996-1999 (Sample 1)		
		All	$S_{i,t} > 0$	$S_{i,t} > 0$ & $S_{i,t'} > 0$
Number of firms		314	300	296
Paris	cl3	54	50	49
Lyon	cl2	25	22	21
Nanterre	cl1	13	13	13
Strasbourg	cl9	15	15	15
Evry	cl5	13	13	13
Toulouse	cl4	12	11	11
Bordeaux	cl10	13	13	13
Clermont	cl6	9	8	8
Marseilles	cl11	8	7	7
Antibes		6	5	5
Lille		5	5	3
Nantes	cl12	5	5	5
Rennes		5	5	5
Angers		4	4	4
Montpellier		3	3	3
Not in cluster		124	121	121

	Variable	1999-2002 (Sample 2)		
		All	$S_{i,t} > 0$	$S_{i,t} > 0$ & $S_{i,t'} > 0$
Number of firms		393	375	368
Paris	cl3	60	55	50
Lyon	cl2	39	36	36
Nanterre	cl1	17	16	16
Strasbourg	cl9	20	19	19
Evry	cl5	16	16	15
Toulouse	cl4	16	15	15
Bordeaux	cl10	14	13	13
Clermont	cl6	12	11	11
Marseilles	cl11	11	11	11
Antibes		7	7	7
Lille		6	4	4
Nantes	cl12	8	8	8
Rennes		5	5	5
Angers		6	6	6
Montpellier		6	5	5
Not in cluster		150	148	147

Table 1: Determinants of 1999-2002 sales growth

Dependent variable	[logSales(2002)-LogSales(1999)]/3	
	(1)	(2)
Log Sales (1999)	-0.034^{*}	-0.020^{**}
	(0.007)	(0.009)
Log Age (1999)		-0.046^{*}
		(0.016)
Constant	0.370^{*}	0.361^{*}
	(0.055)	(0.054)
R^2(adjusted)	0.055	0.072
F	22.33	15.02
n	368	360

Figures in parentheses are standard errors.
* significant at 1%, ** significant at 5%, *** significant at 10%.

Table 2: Determinants of 1999-2002 sales growth

Dependent variable	[logSales(2002)-LogSales(1999)]/3	
	(1)	(2)
Log Sales (1999)	-0.209^{*}	-0.190^{*}
	(0.037)	(0.037)
$(\text{Log Sales})^2$ (1999)	0.013^{*}	0.012^{*}
	(0.003)	(0.003)
Log Age (1999)		-0.046^{*}
		(0.016)
Constant	0.923^{*}	0.908^{*}
	(0.127)	(0.127)
R^2	0.114	0.132
R^2(adjusted)	0.109	0.125
F	23.41	18.12
n	368	360

Figures in parentheses are standard errors.
* significant at 1%.

Table 3: Determinants of 1996-1999 sales growth

Dependent variable	[logSales(1999)-LogSales(1996)]/3	
	(1)	(2)
Log Sales (1996)	-0.062^{*}	-0.047^{*}
	(0.009)	(0.011)
Log Age (1996)		-0.013
		(0.021)
Constant	0.616^{*}	0.520^{*}
	(0.066)	(0.065)
R^2(adjusted)	0.144	0.112
F	50.48	19.05
n	296	288

Figures in parentheses are standard errors.
* significant at 1%, ** significant at 5%, *** significant at 10%.

Table 4: Determinants of 1996-1999 sales growth

Dependent variable	[logSales(1999)-LogSales(1996)]/3	
	(1)	(2)
Log Sales (1996)	-0.907^{*}	-0.955^{*}
	(0.108)	(0.107)
$(\text{Log Sales})^2$ (1996)	0.114^{*}	0.126^{*}
	(0.018)	(0.017)
$(\text{Log Sales})^3$ (1996)	-0.005^{*}	-0.005^{*}
	(0.000)	(0.000)
Log Age (1996)		-0.042^{**}
		(0.018)
Constant	2.491^{*}	2.533^{*}
	(0.216)	(0.219)
R^2	0.349	0.341
R^2(adjusted)	0.342	0.331
F	52.19	36.58
n	296	288

Figures in parentheses are standard errors.
* significant at 1%, ** significant at 5%.

Table 5: Determinants of 1999-2002 sales growth

Dependent variable	[logSales(2002)-LogSales(1999)]/3
Log Sales (1999)	-0.181^{*}
	(0.038)
(Log Sales)^2 (1999)	0.012^{*}
	(0.003)
Log Age (1999)	-0.047^{*}
	(0.016)
reg11	0.038
	(0.047)
reg24	0.069
	(0.089)
reg42	0.033
	(0.063)
reg52	0.004
	(0.074)
reg53	0.048
	(0.069)
reg72	0.026
	(0.072)
reg73	0.077
	(0.073)
reg82	0.057
	(0.054)
reg83	-0.048
	(0.078)
reg91	0.052
	(0.083)
reg93	$\mathbf{0.160}^{**}$
	(0.062)
Constant	0.831^{*}
	(0.137)
R^2	0.157
R^2(adjusted)	0.123
F	4.59
n	360

Figures in parentheses are standard errors.
* significant at 1%, ** significant at 5%.

Table 6: Determinants of 1999-2002 sales growth

Dependent variable	[logSales(2002)-LogSales(1999)]/3 (1)	[logSales(2002)-LogSales(1999)]/3 (2)
Log Sales (1999)	-0.204^{*}	-0.189^{*}
	(0.037)	(0.038)
$(\text{Log Sales})^2$ (1999)	0.012^{*}	0.012^{*}
	(0.003)	(0.003)
Log Age (1999)		-0.044^{*}
		(0.016)
cl1	$\mathbf{0.122}^{***}$	0.065
	(0.072)	(0.073)
cl2	0.031	0.022
	(0.050)	(0.050)
cl3	−0.005	−0.006
	(0.044)	(0.042)
cl4	0.060	0.039
	(0.074)	(0.072)
cl5	−0.038	−0.057
	(0.074)	(0.072)
cl6	$\mathbf{-0.153}^{***}$	−0.119
	(0.085)	(0.087)
cl9	−0.023	−0.023
	(0.066)	(0.064)
cl10	−0.009	−0.007
	(0.079)	(0.076)
cl11	$\mathbf{0.175}^{**}$	$\mathbf{0.155}^{***}$
	(0.085)	(0.083)
Constant	0.909^{*}	0.902^{*}
	(0.128)	(0.129)
R^2	0.143	0.152
R^2(adjusted)	0.117	0.123
F	5.42	5.19
n	368	360

Figures in parentheses are standard errors.
* significant at 1%, ** significant at 5%, *** significant at 10.

Table 7: Determinants of 1996-1999 sales growth

Dependent variable	[logSales(1999)-LogSales(1996)]/3
Log Sales (1996)	-0.862^{*}
	(0.108)
(Log Sales)^2 (1996)	0.106^{*}
	(0.018)
(Log Sales)^3 (1996)	-0.004^{*}
	(0.001)
reg11	0.008
	(0.044)
reg42	$\mathbf{0.136}^{**}$
	(0.063)
reg52	0.003
	(0.076)
reg53	0.066
	(0.071)
reg72	0.014
	(0.068)
reg73	0.014
	(0.073)
reg82	$\mathbf{0.166}^{*}$
	(0.057)
reg93	0.098
	(0.064)
Constant	$\mathbf{2.379}^{*}$
	(0.218)
R^2	0.381
R^2(adjusted)	0.357
F	15.88
n	296

Figures in parentheses are standard errors.
* significant at 1%, ** significant at 5%.

Table 8: Determinants of 1996-1999 sales growth

Dependent variable	[logSales(1999)-LogSales(1996)]/3
Log Sales (1996)	-0.873^{*}
	(0.109)
$(\text{Log Sales})^2$ (1996)	0.108^{*}
	(0.018)
$(\text{Log Sales})^3$ (1996)	-0.004^{*}
	(0.001)
gen1	-0.022
	(0.038)
gen2	$\mathbf{0.113}^{***}$
	(0.059)
gen3	-0.003
	(0.074)
gen5	0.111
	(0.075)
gen6	0.006
	(0.083)
Constant	2.436^{*}
	(0.219)
R^2	0.364
R^2(adjusted)	0.346
F	20.52
n	296

Table 9: Determinants of 1996-1999 sales growth

Dependent variable	[logSales(1999)-LogSales(1996)]/3 (1)	[logSales(1999)-LogSales(1996)]/3 (2)
Log Sales (1996)	-0.863^{*} (0.109)	-0.916^{*} (0.108)
(Log Sales)^2 (1996)	0.105^{*} (0.018)	0.118^{*} (0.017)
(Log Sales)^3 (1996)	-0.004^{*} (0.001)	-0.005^{*} (0.001)
Log Age (1999)		-0.042^{**} (0.018)
cl1	0.039 (0.078)	0.032 (0.072)
cl2	0.092 (0.062)	**0.098***** (0.058)
cl3	**−0.078***** (0.044)	**−0.068***** (0.041)
cl4	−0.001 (0.083)	−0.005 (0.080)
cl5	0.082 (0.077)	−0.011 (0.074)
cl9	0.097 (0.072)	0.100 (0.067)
cl10	−0.076 (0.076)	−0.072 (0.071)
Constant	2.446^{*} (0.219)	2.493^{*} (0.224)
R^2	0.373	0.365
R^2(adjusted)	0.351	0.340
F	16.97	14.44
n	296	288

Figures in parentheses are standard errors.
* significant at 1%, ** significant at 5%, *** significant at 10.

Table 10 : Determinants of 1999-2002 rapid growth (basic model)

	Maximum likelihood estimates (standard error)	P>ChiSq
Log Sales (1999)	-0.154^{*} (0.051)	0.003
Intercept	0.864^{**} (0.380)	0.023
n	375	

Table 11 : Determinants of 1996-1999 rapid growth (basic model)

	Maximum likelihood estimates (standard error)	P>ChiSq
Log Sales (1996)	-0.286^{*} (0.062)	< 0.001
Intercept	1.561^{*} (0.456)	< 0.001
n	300	

Table 12 : Determinants of 1999-2002 rapid growth (administrative regions)

	Maximum likelihood estimates (standard error)	P>ChiSq
Log Sales (1999)	**−0.146*** (0.054)	0.006
reg11	0.656 (0.406)	0.106
reg24	0.017 (0.713)	0.981
reg31	0.959 (0.726)	0.187
reg42	0.143 (0.536)	0.789
reg52	0.042 (0.592)	0.944
reg53	0.276 (0.573)	0.630
reg72	0.020 (0.606)	0.974
reg73	**1.091***** (0.591)	0.065
reg82	0.665 (0.450)	0.140
reg83	0.549 (0.603)	0.362
reg91	**1.556**** (0.693)	0.025
reg93	**1.180**** (0.512)	0.021
Intercept	0.256 (0.530)	0.630
n	375	

Table 13: Determinants of 1999-2002 rapid growth (genopoles)

	Maximum likelihood estimates	P>ChiSq
Log Sales (1999)	$\mathbf{-0.150}^{*}$ (0.052)	0.004
gen1	0.425 (0.267)	0.111
gen2	0.519 (0.354)	0.142
gen3	$\mathbf{1.027}^{**}$ (0.470)	0.029
gen5	−0.027 (0.535)	0.960
gen6	0.816 (0.565)	0.149
gen8	−0.013 (0.671)	0.984
Intercept	0.585 (0.399)	0.143
n	375	

Figures in parentheses are standard errors.
* significant at 1%, ** significant at 5%, *** significant at 10%.

Table 14: Determinants of 1999-2002 rapid growth (clusters)

	Maximum likelihood estimates	P>ChiSq
Log Sales (1999)	$\mathbf{-0.183}^{*}$ (0.054)	< 0.001
cl1	$\mathbf{1.783}^{*}$ (0.614)	0.004
cl2	0.473 (0.372)	0.204
cl3	-0.091 (0.321)	0.776
cl4	0.860 (0.553)	0.120
cl5	0.279 (0.538)	0.604
cl6	0.065 (0.630)	0.918
cl9	-0.264 (0.523)	0.614
cl10	-0.388 (0.625)	0.535
cl11	$\mathbf{1.321}^{***}$ (0.701)	0.060
Intercept	0.902^{**} (0.407)	0.027
n	375	

Table 15: Determinants of 1996-1999 rapid growth (administrative regions)

	Maximum likelihood estimates (standard error)	P>ChiSq
Log Sales (1996)	-0.295^{*} (0.065)	< 0.001
reg11	0.107 (0.361)	0.767
reg42	**0.832***** (0.497)	0.094
reg52	-0.113 (0.624)	0.856
reg53	0.826 (0.567)	0.145
reg72	0.015 (0.572)	0.979
reg73	0.635 (0.582)	0.275
reg82	0.724 (0.453)	0.110
reg93	0.595 (0.509)	0.242
Intercept	1.316 (0.512)	0.010
n	300	

Table 16 : Impalas, 1999-2002 (administrative regions)

	Maximum likelihood estimates (standard error)	P>ChiSq
Log Sales (1999)	$\mathbf{-0.825}^{**}$ (0.324)	0.011
(Log Sales)^2 (1999)	$\mathbf{0.116}^{*}$ (0.024)	< 0.0001
Log Age (1999)	$\mathbf{-0.775}^{*}$ (0.184)	< 0.0001
reg11	$\mathbf{1.540}^{*}$ (0.567)	0.007
reg31	−0.005 (1.108)	0.996
reg42	1.134 (0.714)	0.113
reg52	0.434 (0.985)	0.659
reg53	0.486 (0.830)	0.558
reg72	$\mathbf{1.418}^{***}$ (0.789)	0.072
reg73	1.092 (0.776)	0.159
reg82	0.889 (0.645)	0.168
reg83	1.166 (0.868)	0.179
reg91	0.383 (1.220)	0.754
reg93	$\mathbf{1.829}^{*}$ (0.685)	0.007
Intercept	−1.549 (1.178)	0.189
n	367	

Table 17: Impalas, 1999-2002 (genopoles)

	Maximum likelihood estimates	P>ChiSq
Log Sales (1999)	**−0.818*** (0.317)	0.0099
(Log Sales)^2 (1999)	**0.114*** (0.024)	< 0.0001
Log Age (1999)	**−0.778*** (0.177)	< 0.0001
gen1	**0.827**** (0.358)	0.021
gen2	0.292 (0.501)	0.560
gen3	0.748 (0.633)	0.237
gen5	0.531 (0.677)	0.433
gen6	0.134 (0.752)	0.858
gen8	−0.208 (1.100)	0.850
Intercept	−0.741 (1.091)	0.497
n	367	

Figures in parentheses are standard errors.
* significant at 1%, ** significant at 5%, *** significant at 10%.

Table 18: Impalas, 1999-2002(clusters)

	Maximum likelihood estimates	P>ChiSq
Log Sales (1999)	$\mathbf{-0.866}^*$ (0.317)	< 0.006
$(\text{Log Sales})^2$ (1999)	$\mathbf{0.117}^*$ (0.024)	< 0.0001
Log Age (1999)	$\mathbf{-0.773}^*$ (0.181)	< 0.0001
cl1	$\mathbf{2.078}^*$ (0.725)	0.004
cl2	0.071 (0.525)	0.893
cl3	0.572 (0.438)	0.192
cl4	0.433 (0.689)	0.530
cl5	0.431 (0.652)	0.509
cl6	−0.207 (1.110)	0.852
cl9	0.329 (0.659)	0.617
cl10	0.587 (0.785)	0.455
cl11	1.211 (0.754)	0.108
Intercept	−0.555 (1.082)	0.608
n	367	

Table 19 : Impalas, 1996-1999 (administrative regions)

	Maximum likelihood estimates (standard error)	P>ChiSq
Log Sales (1996)	$\mathbf{-1.341}^{*}$ (0.363)	0.0002
(Log Sales)^2 (1996)	$\mathbf{0.145}^{*}$ (0.028)	< 0.0001
Log Age (1996)	$\mathbf{-0.713}^{*}$ (0.212)	< 0.001
reg11	0.571 (0.508)	0.261
reg42	$\mathbf{1.407}^{**}$ (0.632)	0.026
reg52	0.153 (0.958)	0.873
reg53	0.518 (0.787)	0.510
reg72	−0.712 (0.938)	0.448
reg73	0.326 (0.827)	0.693
reg82	$\mathbf{1.657}^{*}$ (0.568)	0.004
reg93	0.727 (0.727)	0.317
Intercept	0.884 (1.294)	0.495
n	292	

Table 20: Impalas, 1996-1999 (genopoles)

	Maximum likelihood estimates	P>ChiSq
Log Sales (1996)	$\mathbf{-1.362}^{*}$ (0.362)	< 0.001
(Log Sales)^2 (1996)	$\mathbf{0.146}^{*}$ (0.027)	< 0.0001
Log Age (1996)	$\mathbf{-0.673}^{*}$ (0.207)	0.001
gen1	0.265 (0.406)	0.513
gen2	$\mathbf{1.417}^{*}$ (0.525)	0.007
gen3	−0.440 (0.988)	0.656
gen5	$\mathbf{1.347}^{**}$ (0.649)	0.038
gen6	0.911 (0.815)	0.264
Intercept	1.169 (1.250)	0.349
n	292	

Figures in parentheses are standard errors.
* significant at 1%, ** significant at 5%, *** significant at 10%.

Table 21: Impalas, 1996-1999 (clusters)

	Maximum likelihood estimates	P>ChiSq
Log Sales (1996)	$\mathbf{-1.366}^{*}$ (0.367)	< 0.001
$(\text{Log Sales})^2$ (1996)	$\mathbf{0.144}^{*}$ (0.028)	< 0.0001
Log Age (1996)	$\mathbf{-0.680}^{*}$ (0.2101)	0.001
cl1	0.850 (0.706)	0.228
cl2	$\mathbf{1.327}^{**}$ (0.534)	0.013
cl3	−0.048 (0.493)	0.922
cl4	0.830 (0.810)	0.306
cl5	0.026 (0.816)	0.974
cl9	$\mathbf{1.071}^{***}$ (0.633)	0.091
cl10	−1.178 (1.141)	0.302
Intercept	1.398 (1.269)	0.270
n	292	

Table 22: Venture capital investment in France (1992-2003)

Year	1992	1993	1994	1995	1996	1997
Total amount (M€)	1011	914	1096	751	876	1259
Year	1998	1999	2000	2001	2002	2003
Total amount (M€)	1788	2816	5304	3287	5851	3643

Source: AFIC