Fluid Dynamics and Outliers: Outstanding Performance of High-Tech Companies in Microfluidic Technologies

THÈSE N^{O} 7860 (2017)

PRÉSENTÉE LE 3 NOVEMBRE 2017
AU COLLÈGE DU MANAGEMENT DE LA TECHNOLOGIE
LABORATOIRE LEM
PROGRAMME DOCTORAL EN MANAGEMENT DE LA TECHNOLOGIE

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

POUR L'OBTENTION DU GRADE DE DOCTEUR ÈS SCIENCES

PAR

Bernard André Vincent CALISTI

acceptée sur proposition du jury:

Prof. B. M. C. Oberle, président du jury
Prof. Ph. Wieser, directeur de thèse
Prof. D. Poulin, rapporteuse
Prof. E. Vogler, rapporteur
Prof. C. Tucci, rapporteur

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Suisse
2017

« Tous les géomètres seraient donc fins s'ils avaient la vue bonne, car ils ne raisonnent pas faux sur les principes qu'ils connaissent ; et les esprits fins seraient géomètres, s'ils pouvaient plier leur vue vers les principes inaccoutumés de géométrie. »

Pascal, *Pensées*, édition de Port-Royal, XXXI

Acknowledgments

In Gratitude.

It is a lot better to have written a PHD dissertation than to actually be writing one!

Writing a thesis requires a substantial amount of patience, organization and discipline, all qualities that I lack and that delivering verbal courses do not truly encourage.

That is why during these years of research, I was very dependent on many others who had these same qualities in far larger degree, and whose wisdom helped giving shape to this work in so many ways.

Given the theoretical backbone of this dissertation around doubt and uncertainty, I do not pretend to perfection! This work is certainly full of biases and the body of information used does not pretend to absolute veracity; even if all the evidence was elaborated meticulously and with the utmost care! For knowledge as a whole relates at the same time to the source and to the result of human representations.

Many thanks to my intimate “Tribe”: Nina, Robin, Pauline, Sylvain and Catherine to whom this document is dedicated. I am not only in debt with them for their patience, but I am every day feeling blessed for their unbelievable faith and love.

Thank you to my thesis director Prof. Philippe Wieser who was a terrific supervisor in all respects. I could not dream of a better one.

Thank you to my parents, to my sister Laurence, to Emilie and family.

Thank you to Josiane Hudry whose organizational skills and software know-how was a permanent and invaluable support.

Thank you to Laurent Martin for his high quality contribution in the chapters requiring too creative and sophisticated mathematics for me alone.

Thank you to Rossana Diffalah who produced high-quality contributions always on a demanding schedule.

Thank you to Richard Woodward for his repeated high-level British contribution to improve my insufficient English.

A special thanks to Chris Tucci for his flair in so many matters and for bringing me into the MOT family along with Jean Micol.

Thank you to Clayton Christensen who was so inspiring to me.

Thank you to my EPFL colleagues who trusted me to manage the expectations of the dissertation effectuation.

Thank you to Marianne and Christiane, and to the other members of IML and MOT back office. They were always ready to help.

Thank you to my EMLyon colleagues for their help when it was necessary.

Thank you to Barbara Montalan and Robert Salle for reminding me regularly the importance of finishing the thesis work.

Thank you to Cathy Pardo, to Philippe Monin and Bernard Forgues for providing their advices.

Thank you to Alain Hudry, Alain Dunand and my Ardeje and Ideo teams whose influence is reflected in their impressive knowledge in science as a whole.

Thank you to Christine Wieser for her multiple signs of exceptional friendship and support.

Thank you to Pascal Pierron and Patrice Giraud for having served as facilitators at crucial moments along the way.

Thank you for all the inspirational interviewees and readings' authors that this dissertation enabled to meet.

I am also grateful to my students, with whom I have discussed and refined the ideas put forward in this document. After class, I was often wondering who had learned the most from our interactions.

I am similarly indebted to the many executives and employees of companies in the inkjet industry who opened their memories and records to me as I tried to understand in details their business models.

Their industry's incremental -and sometimes disruptive evolutions formed the conceptual backbone for this dissertation. I hope it is a useful tool for understanding the individual trajectory of their companies.

I am deeply in debt to all the persons cited above and to so many others.

So I promise to offer as many cups of coffee or tea to celebrate with the people I will meet and who were interested in this work!

The work began when Professor Philippe Wieser took the risk of admitting a middle-aged man into the EPFL's doctoral program in 2010. In addition to this mentor, Professor Chris Tucci also helped throughout my doctoral research to keep my standards for evidence high. I will be forever grateful for all the time of their busy lives they devoted to me.

They deserve some of the first cups.

Abstract

Fluid Dynamics and Outliers:
Outstanding Performance of High-Tech Companies in Microfluidic Technologies' Clusters.

The current craze for unicorns and other hyper growth companies brings a novel interest in what makes the exceptional performance of a firm.

Literature about technological innovation explains the bond between the performance level reached by a company and its ability to promote radical innovations.

But if the theory of disruption enables to validate various levels of innovation, it faces difficulties to define more accurately the drivers of hyper growth.

This thesis comprises five main moments to better understand what drives fast growing young technological companies. To survey this question we have defined one single scientific field, namely microfluidics, focusing on active clusters and spinoffs from the same parent in this sector.

The first phase aims at highlighting evolutionary prospects about scientific enhancements in microfluidics leading to successful innovations. It shows that there is no innovation "due to succeed" and that technical innovations do not make progress as linearly as usual technological trees found in academic literature could suggest. That leads to a kind of rewriting in the evolution of inkjet technology.

The second phase intends to explore performance among groups of spinoffs from the same parent. We consider the clusters in microfluidics and specifically the one in England and the French one.
We consider then. It appears that all these firms are developing and most of them growing, but they do not reach the same degree of performance.
From far, yet, the differences in performance do not clearly appear. To explain variations, we study each spinoff's growth during the 5 first years after launching before comparing with the growth during the 5 first years of the mother company. We have to look in details to the European clusters, to see also technology variants. A fractal approach is thus enabling to understand that performance of firms is like hidden in technology layers.

The third moment elaborates on the relationship between a superior technology and an outstanding performance level. In the case of spin off performance we are not at a stage where we could put the phenomenon under equation! The context is indeed displaying too many (uncontrollable) variables. That is why it was appropriate to survey the scientific and technological clusters in Europe from a case study perspective. It appears then that seemingly similarly disrupting technologies do not end up capturing similar value. In fact, slight differences in the technologies used are leading to massive differences in performance. We discover in the end that one single variable is rooting Outstanding Performance.

In a fourth phase we restate the initial question to better understand what makes Outliers and Outstanding Performance. Where we show that exceptional value capture is coming from exceptionally fitting of the technology considered to a very specific application. Outstanding Performance is thus attached to an extraordinary EBITDA.
The last moment of the dissertation is devoted to ultimately check findings. For that purpose, knowing that real signals can easily be mistaken for informational "noise", we used an evaluation pattern previously elaborated.
This measure is applied to other companies than the ones defined at origin in the clusters. They belong to different industrial sectors than microfluidics, or they develop different inkjet technologies than the ones develop in the clusters surveyed.

The whole checking process eventually led to the conclusion that outliers and outstanding performance are permanently referring to a kind of "uniqueness" embedded in the various cases of exceptional value capture.
Such a unique feature, qualifying outliers among technological startups, makes by itself a research topic.
As more and more attention is given to specific statistical populations, not only could this research contribute to improve the knowledge about hyper growth companies but it could also impact methods in statistics; and beyond methods: statistics themselves as a discipline.

Keywords

Outliers, evolution theory, fluid jetting from circular orifices, disruption theory, technology trees, outstanding performances, DOD and CIJ technologies, hyper growth, scientific clusters.

Résumé

Dynamique des Fluides et Exceptions :

Performance Extraordinaire d'Entreprises High-Tech dans les Clusters spécialisés en Technologies Microfluidiques.

L'engouement actuel pour les licornes et autres entreprises d'hyper croissance relance la question de ce qui fait la performance exceptionnelle d'une entreprise.

La littérature sur l'innovation technologique établit le lien entre le niveau de performance d'une entreprise et sa capacité à promouvoir des innovations radicales.

Mais si la théorie de la rupture permet de qualifier des niveaux d'innovation, elle peine à définir plus précisément les moteurs de l'hyper croissance.

Ce travail de thèse comprend 5 moments principaux pour mieux comprendre ce qui fait le moteur des jeunes entreprises technologiques à forte croissance. Pour étudier cette question, nous avons défini un seul champ scientifique, à savoir la micro-fluidique, centrant l'étude sur des entreprises issues du même parent et les clusters actifs dans ce même secteur.

La première phase du travail vise à mettre en relief les perspectives évolutionnistes attachées aux innovations réussies et générées par des avancées scientifiques en micro-fluidique. Cela montre qu'il n'y a pas d'innovation « programmée pour réussir » et que les innovations techniques ne progressent pas d'une manière aussi linéaire que les arbres technologiques habituellement trouvés dans la littérature académique peuvent le laisser penser. Ce qui conduit à une sorte de réécriture de l'évolution de l'inkjet en tant que technologie.

La seconde phase du travail se propose d'explorer la performance telle qu'elle apparait dans des groupes d'entreprises issues d'une même compagnie-mère. Nous considérons les clusters en micro-fluidique, et en particulier le cluster Anglais et le cluster Français. Il apparait que toutes ces entreprises se développent et que la plupart d'entre elles sont en croissance. Mais elles n'atteignent pas les mêmes niveaux de performance,.

Vu de loin, pourtant, les différences de performance n'apparaissent pas vraiment. Pour expliquer les variations nous étudions la croissance de chaque spinoff durant les 5 premières années après le lancement avant de comparer avec la croissance durant les 5 premières années de la compagnie-mère. Nous devons regarder en détails les clusters européens pour identifier aussi les variantes technologiques. Une approche fractale permet ainsi de comprendre que la performance des entreprises est comme cachée dans les couches de technologie.

Le troisième moment détaille la relation entre une technologie supérieurement efficace et un niveau de performance extraordinaire. Dans le cas de la performance de «spinoffs » nous n'en étions pas à un stade où nous pouvions mettre le phénomène en équation. Le contexte manifeste en effet trop de variables (incontrôlables). C'est pourquoi il était approprié d'étudier les clusters scientifiques et techniques en Europe sous l'angle d'une étude de cas.

Il s'avère que des technologies apparemment similaires ne conduisent pas à des captures de valeur identiques. En fait, de légères différences dans les technologies utilisées amènent à de fortes différences de performance. Nous découvrons finalement que la Performance Exceptionnelle se développe à partir d'une seule variable.

Dans un quatrième temps, nous reformulons la question initiale pour mieux comprendre ce qui fait la performance exceptionnelles et les exceptions. Où nous montrons qu'une capture de valeur exceptionnelle provient d'une adéquation exceptionnelle entre la technologie considérée et une application très spécifique. La performance exceptionnelle est ainsi liée à un EBE extraordinaire.

La dernière partie de la dissertation est consacrée à une ultime validation des résultats. Pour ce faire, sachant qu'il est facile de confondre du « bruit » informationnel avec de réels signaux, nous avons utilisé un cadre d'analyse préalablement élaboré.
Le mode de mesure en question est appliqué à d'autres entreprises que celles définies à l'origine dans les clusters. Elles sont rattachées à d'autres secteurs que la micro-fluidique, ou elles développent d'autres technologies jet d'encre que celles exposées dans les clusters étudiés.

Le processus de validation dans son ensemble aboutit finalement à la conclusion que les exceptions font référence en permanence à une sorte « d'unicité », enchâssée dans les différents cas de capture de valeur extraordinaire. Cette qualité unique manifestant les exceptions parmi les startups technologiques, constitue par elle-même un sujet de recherche.
Dans la mesure où de plus en plus d'attention est portée sur les populations statistiques spécifiques : Non seulement cette recherche pourrait contribuer à améliore la connaissance des entreprises d'hyper croissance, mais elle pourrait aussi avoir un impact sur les méthodes statistiques et au- delà même de ces méthodes : sur les statistiques elles-mêmes en tant que discipline.

Mots-clés

Exceptions, théorie de l'évolution, projection de fluides à partir d'orifices circulaires, théorie de l'innovation radicale, arbres technologiques, performances remarquables, technologies goutte-à-la demande et jet continu dévié, hyper croissance, grappes scientifiques.

Graphic Table of Contents

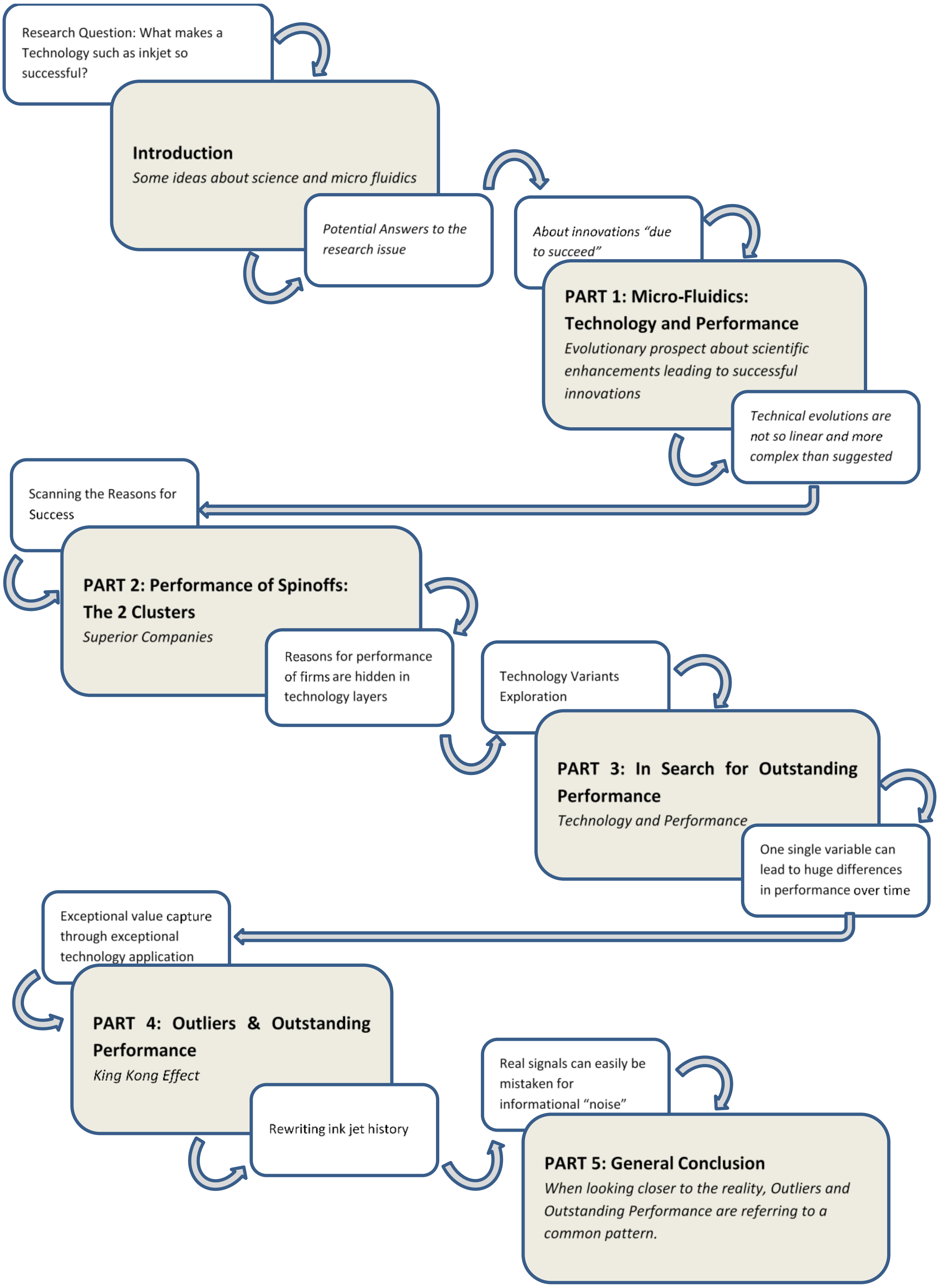


Table of Contents

List of Figures

List of Equations

List of Tables

INTRODUCTION

1- Vision

As Levy-Strauss changed the way westerners view « primitive people », we have the ambition to modify, even if very slightly in our case, the way people ordinarily view successful innovations.

We also intend to build somewhat a bridge over the « Great Divide » between Research and Practice.

For us management is an applied science. Consequently we try and understand the reality around us so as to turn this understanding into an effective tool for managers.

This desire to apply research does not imply reducing science to a collection of techniques.

Quite the opposite, there is no limit to our respect for what is abstract and intellectual.

This same respect pushes us to reject an idea based on the irreconcilable distance between management of technology theory and management of technology practice.

It is with an affirmed intellectual requirement that we have sought throughout our work to stick as close as possible to what founded Cartesianism and the entire science: the idea that it is essential to radically challenge established thinking and assertions that have been commonly accepted.

2- Context: Early stages and evolution of the dissertation

The first ideas about this PHD project are going back to 2003, when the EM-Lyon Research Director at the time was driving me to develop research fields he was considering as unique and very valuable.

From the very beginning, something was obvious to me: I had to do a work in a field related to "hard" sciences.

This will and this interest leaded to consider gradually that Industrial Engineering and Management of Technology as natural fields of research according to my experience but also according to my intellectual areas of interest.

As my dissertation progress was going along, the filiation was indeed clearer and clearer between the works in epistemology – with a very strong mathematical resonance- that I conducted in university during the 80ies! And the research work undertaken in the EPFL framework.

In other terms, there was a close proximity, not temporal but thematic, between the works that we performed at university 25 years apart:

- Those having searched on the "Treatise on Conics" by B. Pascal. It was combining math perspective and sociology of science.
- Those studying "Clusters Specializing in Micro-Fluidics technologies" from a twofold understanding: The research was referring to rules applying in Management of Technology and laws governing fluid mechanics phenomena in Physics.

From 2005 on, the PHD subject evolved whilst keeping focused on the generic theme of technological innovation.

In 2005, thus well before the official registration in the PHD program, the problematic was formulated around issues linked with startups development: To which extend, initial conditions were impacting development trajectories? That seemed to be a fruitful formulation.
Then, a whole series of issues succeeded during the 4 years that followed:

- Innovation and SMEs: Are innovation processes SMEs-specific?
- Relationships between innovation and entrepreneurship: What about Entrepreneurship without innovation? And what about the opposite?
- Ramp up: From business plan to the very first order
- Institutional support: A cause of performance inequality or a consequence?
- Metrics for technological innovation projects.
- High-tech new ventures and strategic speed-up.
- Business models for non-existing ventures.
- High-tech ventures and slow growth.
- Innovation efficiency: Between disruptive and incremental technological enhancements.
- Do the reasons explaining how and why spinoffs start, explain their performance over time too?
- Evolutionary theory of technological innovation: Lamarckian and Darwinian adaptations.

Eventually, after 2010 and the beginning of the doctoral program, it became clear that we would concentrate the research on a specific scientific field: Micro-fluidics.

It was also clear that in this field, the PhD work would mainly deal with innovation and spinoffs.

But again the questioning evolved: From “do technological ventures better resist to crisis: the case of micro-fluidics clusters?” To “performance of spinouts from the same anchor in micro-fluidics” and to “what dynamics underpin spin offs performance in micro-fluidics?”
And finally: Fluid Dynamics and Outliers: Outstanding Performance of High Tech Companies. in Micro-Fluidic Technologies’ Clusters.

Chapter 1 - MICRO-FLUIDICS: TECHNOLOGY AND PERFORMANCE

In this part we are going to deal with the technological substrate of performance.

For through innovation, technology is well 1 performance element.

Thus, under some conditions, encouraging firms to innovate leads to improved economic performances (Sirelli, 2000; 61).

But the meaning of Technology and Innovation is shadowed by a plurality of definitions.

In our case we will use the concept of technology as “the Science of Technics”, in the tradition of A-G Haudricourt.

Besides, we understand the idea of performance based on a multi-criteria approach.
Alfred Sloan had popularized a financial approach to company performance based on the ROE/ROI (and therefore on the added value).

But the literature has, for a number of years, been turning to a multi-criteria approach to measure performance. The use of just one performance criteria, like profitability, is no longer felt to be sufficient as it more often reflects short term data as opposed to organizational reality.

Thus, Barney (1997) managed to explain it by showing that profitability is not a criterion that reflects a company’s capability to survive in the long term.

Among the criteria that the literature uses to measure performance, one, the survival rate, proves yet to be the most evident criterion for companies that have just been created (Cooper). So long as there is no correlation between this characteristic – being a survivor - and other performance criteria like the growth rate (Cooper & Gimeno-Gascon & Woo, 1991, quoted by Cooper).

According to Cooper, comparing surviving companies is traditionally based on four types of performance measures:

- **Growth:** in terms of turnover and number of employees.
- **Company size** (« Absolute size »).
- **Objective Criteria:** mainly the financial ratios.
- **Subjective Criteria.**

Generally speaking the last type of these performance measures is not used very much and only proves to be necessary when reliable financial data are unavailable. The criteria to measure performance can therefore be put into three groups which is an approach that we have applied to our work :

1. **Financial ratios.**

   These give us the profitability (Burley& Westhead), that can be calculated from the pre-tax result (or the EBITDA).

2. **Growth.**

   It is in itself a composite criterion, made up of different elements like:

   - Growth in turnover and profit (Burley& Westhead).
   - Just growth in turnover (Hmielski & Corbett).

3. **Company size**

   The main criterion used in this area is job creation; this amounts to measuring the number of employees. An approach adopted by Reynolds; and likewise by Birley & Westhead .

It is within the performance evaluation framework set out above that we analyze the development of ink jet.

Thus, and we will explain in more detail, it is important to point out that companies that have invested in ink jet over the last fifty years seem to have focused on 1 single performance pathway.

Since the successful launching in 1984 of both HP's Thinkjet and Canon's Bubblejet, the digital printer market worldwide has evolved dramatically:
Digital printing trends show that the digital share of the total print market will exceed 20 % in 2018, coming from less than 10 % in 2008. When, and only by referring to desktop printers, we state that: between 1984 and 2010, the installed base reached something like 250 million printers installed worldwide.
To be more accurate, 260 million desktop printers were installed worldwide in 2011. And more than 105 million units were shipped in 2010.

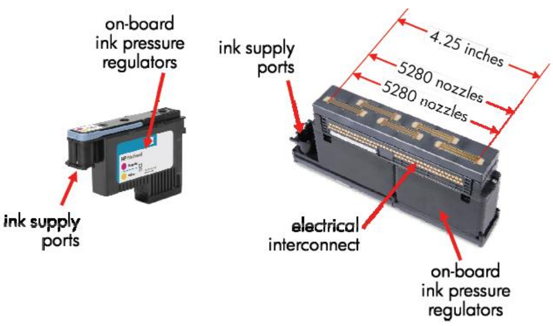


Fig.1 Basic components of a desk top inkjet printer (Ref. Epson)

Moreover, according to the latest research from Smithers Pira, the compound average annual growth rate of the sector will still exceed 7% in the 5 years ahead of 2013 (2013-2018 prospective survey).

Hence, the digital printing market will go from 131,5 billion USD in 2013 to almost 188 billion USD in 2018 (IMI, 2008).

In the shipments, ink jet amounts to 75 %, the remaining digital printers being represented by laser devices (Lyra, 2011).

1.1 Evolutions in ink jet: some landmarks for the technology

The analysis framework combining technologies and applications - application understood as *« the special use or purpose to which a technology is put »* - is relevant to be able to give an approximate evaluation of a technology's potential (Nelson and Winter, 1982) at any given « M » moment.

Indeed, the (potential) strength of the disruption that is produced by a new technology in a given technical system makes this evaluation possible. It takes the shape of a scale, like the ones used for measuring earthquakes' intensity.

But only a ***clear*** understanding of a technology enables the potential performance limits for specific applications to be anticipated.

In the present chapter, by presenting an overview of the main inkjet technology developments, we clarify the importance of inkjet technology as key-technology for today's industry, and provide the fundamental knowledge needed to discuss further limits and applications.

This chapter will also outline basic printing principles.

1.1.1 Presentation of the technology and its positioning

This technology is referring to what it is not!

It is not electro-photography and it is not thermography.

Originally set up in 1858, it owes its industrial development mostly to Siemens and Epson in the 1950ies and 1960ies.

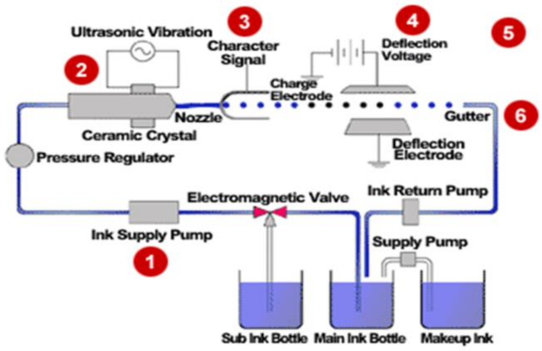


Fig. 2 Scheme of the first (1970) CIJ printer, in Ink Jet Science PG, spring 2012

2 main technologies are competing in terms of speed and printing quality:

1- Continuous Ink Jet (CIJ): very small droplets are passing continuously through a magnetic field to orientate the jet.

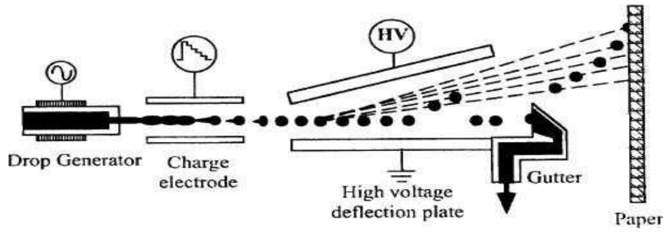


Fig. 3 Continuous inkjet printing (www.image.com)

2- Drop On Demand (DOD): Only the drops necessary to the print are directed to the substrate.

In this later scheme, drops are ejected:

- Thanks to a mechanical transfer;
- By a thermal excitement;
- Or by a piezo-electric effect.

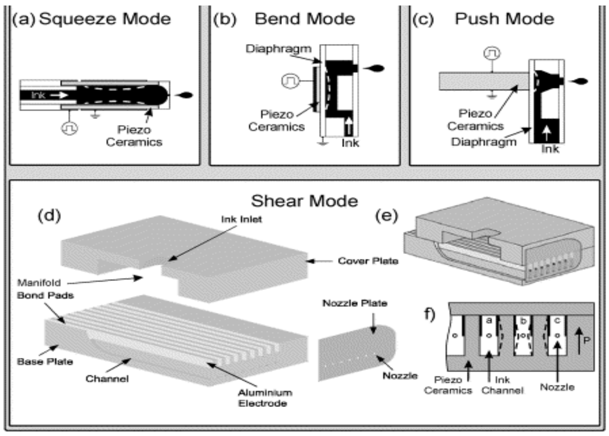


Fig. 4 Map of piezoelectric DOD inkjet technologies. (Reference: P.Pierron / Dickson 2003)

These two main technologies are enabling presently to reach print quality standards up to 2 400 dpi and more (Ricoh 3 picolitres / Epson 4 picolitres), and speeds exceeding 500 meters/minute!

Technical data (early 21st century):

	CIJ	**DOD**	**Comments**
Viscosity	1 mPa.s	30 à 500 mPa.s	ref. 2005
Surface Energy	30-40 mN/m	30-50 mN/m	ref. 2005
Drop Volume	10 pl.	3 to 20 pl.	with the same nozzle
Ejection Speed	50 m/s	30 m/s	
Frequency	1 MHz	30 to 40 KHz	
Nozzle Size (microns)	40, 60 or 75	100 to avoid nozzle clogging	ref. 2000
Number of Nozzles (per print head)	some	Up to 1 000	to increase speed and printing coverage

Table 1 - CIJ vs DOD inkjet technologies typical figures

1.1.2 The Difference between DOD and CIJ: 2 markets

There is a technical division splitting into two major families the world of ink jet printers with DOD on one side and CIJ on the other.

But considering the huge variety of applications covered by these two major technical solutions and all the variations and sub-branches around them, looking at the division between markets can be as relevant.

In fact, the inkjet technology covers basically two main types of markets. The great divide between DOD and CIJ is not perfectly matching the division between those two markets.

One market is covering desktop and office printing applications.
The other market is dedicated to commercial and industrial printing.

The environment and the set of constraints are very different in the two cases.

➔ **The desktop and office printers operate indeed in a controlled environment:**

- The distance from head to substrate is constant.
- The substrate is always porous.
- The throughput is low.
- The printer is a stand-alone device.
- The environment of the head is clean.

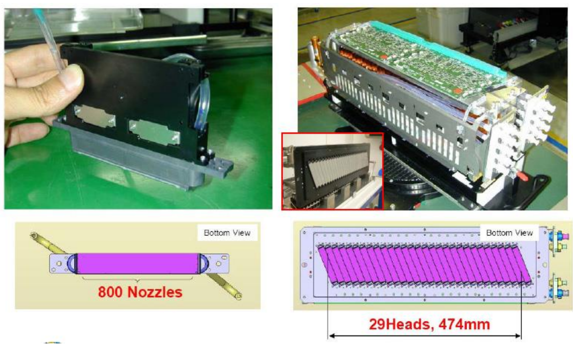


Fig. 5 Example of nozzles, printhead and print module (Ref Panasonic)

➔ **The conditions for commercial and industrial printing are more diverse and less stable:**

- The materials to be printed can vary.
- The distance head/substrate is not standard.
- The substrates can be uneven or not always oriented the same way.
- The environment of the printer can be affected by humidity, temperature changes, dirt … Or not!
- The output rate can go from very low to exceeding technological limits!

1.1.3 Structure of a printer

An inkjet printer gathers in a same cabinet:

- A printing system with its printing head(s) (usually one for each color) and its ink circuit.
- A RIP ("Raster Image Processor") : This is the software part of the system transforming the digital files describing the "page" (message) to be printed received from the computer in a language directly understandable by the printer. This relates to information about the position of head(s) and the modulation of the quantity of ink to be jetted according to the chosen raster.
- An ink adapted to the printing head and to the application targeted.
- A user interface to define the messages and monitor the printing.

Sometimes (depending upon the technology):

- A module with a head positioning system.
- An optimized substrate for a better print quality. The reference is paper, but other substrates are more and more used.
- Plus the device to move the heads and/or the paper.

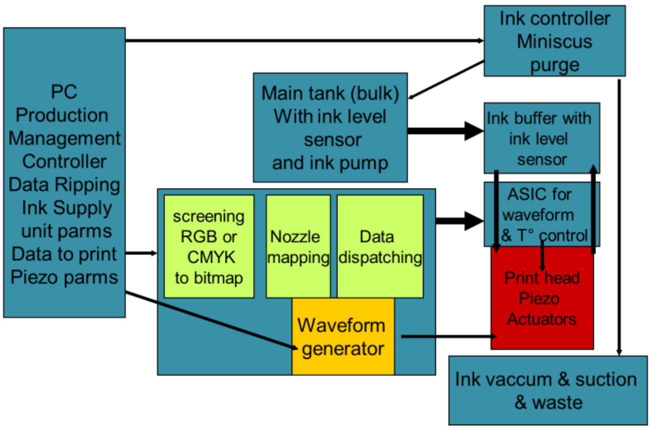


Fig. 6 Print engine architecture, in Ink Jet Science spring 2012

The requirements to meet the needs in many other areas than printing onto paper justify the intensive research program conducted in the last 50 years (cf. following pages).

1.1.4 Methodology:

Working on the technological side of the dissertation was enabled mainly through 5 processes:

- Discussions with experts.
- Gathering of personal previous available knowledge.

- Additional classes and trainings in microfluidics.
- Reading of scientific thesis in microfluidics.
- Participation to major events in digital printing like Drupa 2012 (see fig. below).

Fig. 7 DRUPA 2012 (exhibition): example of a large format flatbed printer.

1.2 Updated historical overview on inkjet technology

(For more details see APPENDIX 5 - Addendum about inkjet history)

1.2.1 Early stage

The rapid development of inkjet technology started off after 1950.

About one century ago, in 1858, the first inkjet-like recording device, using electrostatic forces, was invented by William Thomson, later Lord Kelvin. This was the Siphon recorder as shown in Fig. 8
The apparatus was used for automatic recordings of telegraph messages and was patented in 1867.

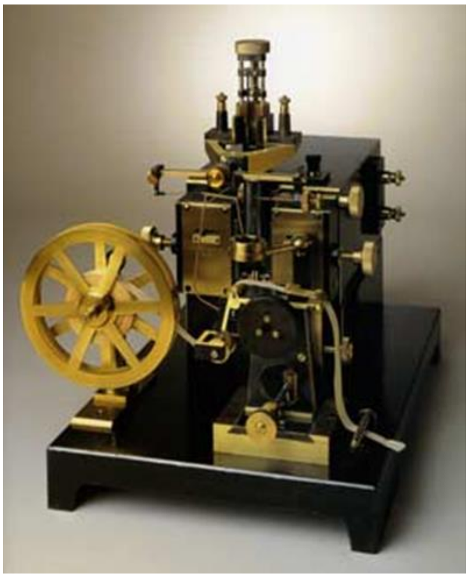


Fig. 8 The Siphon recorder is the first practical continuous inkjet device (Ref. Pagora 2012).

A siphon produces a continuous stream of ink onto a moving web of paper and a driving signal moves the siphon horizontally back and forth.

The first experiments on manipulating a stream of droplets even goes back to 1749.

That year, Abbé Nollet published his investigations on the effects of static electricity on a drop stream.

Fig. 9 Nollet, Jean-Antoine. *Leçons de physique expérimentale*, (Ref. Durand editor, 1767-1769. Pl.2)

In 1822 the equations to describe the motion of fluids were formulated by the French engineer and physicist Claude Navier, seventy years after Euler published his equation for ideal liquids without viscosity.

Navier also formulated the general theory of elasticity (reversible deformation) in a mathematically usable form in1821.

On his side, George Stokes introduced his equations for the motion of liquids in 1845.

Hence the name Navier-Stokes for the equations applied in fluid mechanics to a continuum, under the assumption of a strain rate that is linear with the stress. A consequence of that property is the ability to master the quality of the deposition through the monitoring of the pressure in the ejection chamber of a printer.

Now, as far as modern inkjet technology is concerned, its reference formulation is attributed to the Belgian physicist Joseph Plateau and the English physicist Lord Rayleigh.

1.2.2 Equations and what they really mean

We intend to show the importance of works like the ones of Rayleigh for the understanding of the numerous possibilities offered by microfluidics technologies.

We are specifically interested in the fundamental equations for a fluid with a free surface.

$$Ra = \frac{g\beta}{\nu\alpha}(T_s - T_\infty){L_c}^3 = Gr \cdot Pr$$

Equation 1 – Rayleigh formula

with

- g - acceleration due to gravity
- L_c - characteristic length
- T_s – wall temperature
- T_∞ - fluid temperature far from the wall
- ν - kinematic viscosity
- α - thermal diffusivity
- β – volumetric thermal expansion coefficient

This fundamental number illustrates the thermal diffusion in a fluid. Besides this number is a-dimensional.

There are very important consequences in the understanding of this mathematical formula. Indeed, in an industrial environment, most printing heads are highering the temperature of the fluid to be ejected. Taking into account the constant ratio (a-dimentional number), between viscosity, temperature and speed is key. For this enables to simulate and define equilibrium levels to generate, for example, the targeted drop sizes (quality).

Moreover, the knowledge of thresholds effects enables also to envision innovation possibilities. Indeed, Rayleigh number applies to Newtonian fluids up to specific temperature values. Beyond these limits, phenomena are going into chaos and become far more difficult to master. But these very turbulences are opening the door to new technical solutions and new possibilities. Bubble jet technology contributed to that. For these phenomena are not to be observed directly on the nozzle plate side, but near the heater instead.
But to get this, the searcher interested in these supra critics and unstable conditions, needs to show a true exploration mindset.

Eventually, this kind of equations aims at explaining the behavior of inks and other technical fluids mostly “after the nozzle”.
That means at a moment when the liquid, after having been strictly constraint in circuits within the printer, is suddenly exposed in the open-air.

The brutal disappearance of the constraints and the difficulty to predict the fluid behavior “after the nozzle”, are justifying the abundance of the scientific works dealing with the ejection. This moment happens once the shear effect related to the flow through the nozzle has occurred.

Besides, the fact that the Rayleigh number is a-dimensional makes calculations easier by enabling approximations.

In other words, this kind of mathematical data leads to neglect some dimensions as the size of the nozzles considered, for the Rayleigh number appears to be independent from this variable.

Of course, these fractal methodologies based on fixed invariants find their limits! This happens when changing scale.

Thus, if we follow the same example, and even if ***in theory*** the size of a nozzle does not influence the flow equation, no serious practitioner would imagine a process with a nozzle diameter in the order of one centimeter!

AND these findings are leading to many consequences about applications that can be covered or not by a given technology. Hence, the relative performance of companies targeting such or such application will be affected (this thesis).

Coming back to history, Plateau was the very first to publish on this field with his article “On the recent theories of the constitution of jets of liquid issuing from circular orifices”, in 1856. He then derived the relationship between jet diameter and drop size in 1865.

On his side, Lord Rayleigh published a series of founding papers starting with Instability of jets in 1878.

Yet, it took many decades before applications of the physical principles of drop formation were used in commercial and industrial running devices.

In the early 1960s, Prof. Sweet from Stanford University demonstrated that, by applying a pressure wave pattern to an orifice, the corresponding fluid stream could be broken into droplets of uniform size and spacing.

The A.B. Dick Company elaborated Sweet's invention to be used for alpha numeric character printing. With their Videojet product, they launched the first commercial CIJ printing machine in 1968.

Fig. 10 1st printer (Ref. Ink Jet Science spring 2012)

But, instead of continuously firing drops it is also possible to create droplets only when a pulse is actuated: you get drops "on-demand"!

At origin, drop-on-demand (DOD) printers seemed to present some major advantages over CIJ printers: The facts that there is no need for break-off synchronization, charging or deflection electrodes, guttering, and re-circulation systems, no need either for high pressure ink-supplies and complex electronic circuitry.

Generally, three patents issued in the 1970s are considered as seminal for DOD Piezoelectric Inkjet Printers (PIJ).

Each of these patents is defining a specific type of drop formation:

- The "Squeeze" mode was patented in 1972 by Zoltan from the company Clevite (US patent 3,683,212).
- The "Bend" mode was patented (US Patent 3,747,120) by Stemme from the Chalmers University and by Kyser and Sears from Silonics (US Patent 3, 946,398) the same year (1973).[1]

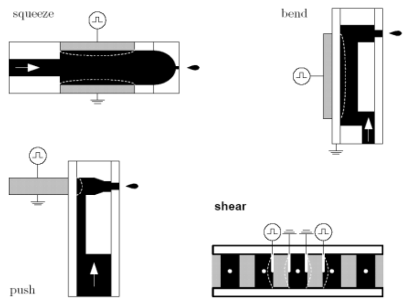


Fig. 11 Taxonomy of printhead technologies (PIJ) according to the deformation mode used to generate drops (Pagora 2011).[2]

In1977, Siemens launched on the market, the very first PIJ DOD printer: The Siemens PT-80, based on Squeeze Mode technology.

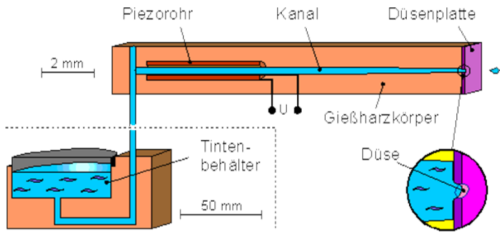


Fig. 12 PT 80 First DOD Piezo. In Ink Jet Science PG, spring 2012
(Courtesy of Siemens)

Silonics company followed with the launching of its bend-mode Quietype in 1978.[3]

The patent of Stuart Howkins (US Patent 4,459,601) from Exxon, describing, in 1984, the Push Mode mechanism; and the patent of Fischbeck (US Patent 4,584,590), featuring the Shear Mode, these two patents are completing the *commonly adopted* taxonomy for DOD PIJ printers. [4]

So, the mainstream of Digital Printing - DOD PIJ, namely –is gathering 4 types of print heads (see fig.12 above).

It is to be mentioned that in the 1960s, another DOD technique was under trial, using principles elaborated by the company Sperry Rand, and based on Sudden Steam Printing.
By bringing aqueous ink to its boiling temperature, drops of ink were generated.
But *the strength of this new design was not immediately acknowledged*, and the company did not elaborate this idea into a commercial product at first.
So, the idea of Thermal Inkjet Printing (TIP) was abandoned until Canon and Hewlett Packard rediscovered it, in the late 1970s (see Appendix page 203.).

Indeed, in 1979 Endo and Hara, two engineers from Canon re-invented the drop-on-demand thermal printer, actuated by an ink vapor bubble. Their product, launched in 1981 was the very first to use the so-called "Bubblejet" concept.

The same year, HP developed its own thermal inkjet technology, leading to the first successful low-cost inkjet printer in 1984.

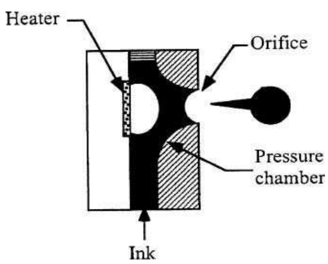


Fig. 13 DOD / Thermal inkjet printing (www.image.com)

The surge of thermal inkjet (TIJ) was not just a new option in digital printing, but it changed inkjet research!

Indeed, by replacing the piezoelectric system by a thermal transducer, the main bottleneck concerning miniaturization was solved.

For the thermal transducer was resuming to a simple, small, and cheap resistor.

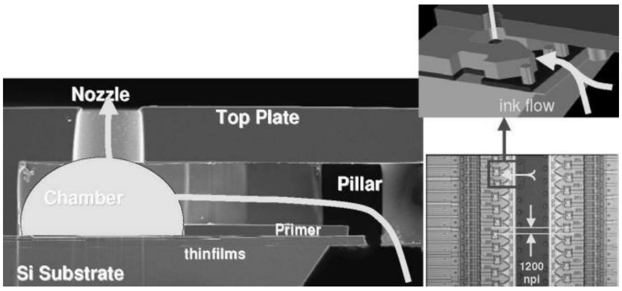


Fig. 14 Side view of HP's SPT printhead, showing the reference-technology in thermal inkjet printing
(Source: P.Pierron / Dickson 2003).

TIJ could then be manufactured using mass-production processes based on IC manufacturing technologies.

This made the cost per nozzle much lower than the cost per nozzle of a pre-existing piezoelectric DOD printhead.

The fact that inkjet printers could at the time be miniaturized along with a low manufacturing cost, leaded to position TIJ as the reference inkjet technology.

So, for an SPT's printhead:

- The outer diameter of the nozzle is 18 μm, when the ink chamber height is 18 μm.
- The nozzle pitch in a single row is 42. 3 μm and both nozzle rows are shifted a half nozzle pitch with respect to each other.

This results in a nozzle resolution of 1200 npi!

HP had solved the reliability problem associated previously with thermal drop on demand Printheads with its concept of *disposable heads*.
And the fact that HP kept increasing the performance of its thermal printheads continuously also explains its success.

Besides, HP claims that TIJ can jet everything that nucleates like toluene, silver suspensions, and even functional proteins.

Currently, thermal inkjet, with top-shooters from HP, Canon and Lexmark, and side-shooters from Canon (the first series) and Xerox, dominates the low-end SOHO (Small Office and Home) color printer market.

After the introduction and broad acceptance of TIJ by the market, PIJ research efforts have largely diminished.

However, in TIJ, the spreading and inter-color bleeding of water based inks are constantly critical and often require special coatings on the media surface.

At high productivity levels, cockling and drying of the media can also be considered as issues.

Therefore, solid inks (hot-melt or phase-change inks), requiring piezo actuation represent sometimes preferred alternatives.

In 1984, new initiatives with a bump-mode design were taken by Howtek and Exxon, later acquired by Dataproducts.[5]

The shearmode design came into the field thanks to Spectra in 1984, (patents from Xerox), and later with Brother. Spectra was acquired by Markem, then by Dimatix and finally by FujiFilms.

A specific version of the shear mode is the shared wall variant designed by the British company Xaar.

This company started in 1990 for making real some ideas promoted by Cambridge researchers (English Cluster / see after).

Among other companies having used this concept Brother/Kodak, ToshibaTEC and MicroFab (US) are to be mentioned.

MicroFab is giving us a first opportunity to further illustrate the complexity of evolution for a technology like ink jet and the importance of very detailed knowledge to understand the success or failure of a specific application of this very technology.

MicroFab had indeed developed heads that would accept a temperature up to 180 °C. It was a very promising solution then to deposit drops of tin. But the early enthusiasm with these heads short-lived. For as the surfaces ("captons") were cold (25 °C), the droplets of tin were rolling over the substrate![6]

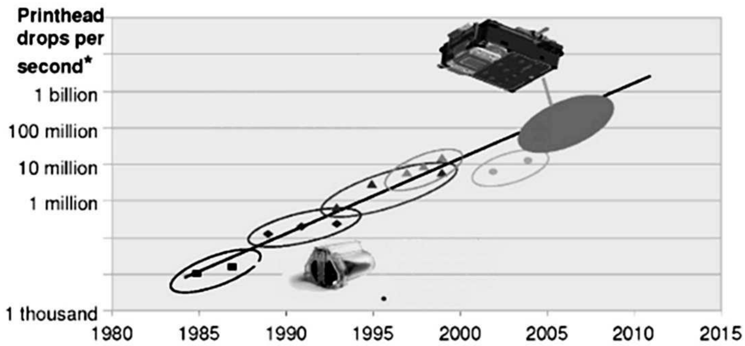


Fig. 15 HP Moore's law (Source: Pagora 2012)

As seen in fig. 15; inkjet printhead performance based on printhead drops per second measurement (the number of nozzles times the maximum drop-on-demand frequency). doubled every 18 months for the past 20 years.
It started with 12 nozzles in a single color glass chip in 1984. Via different printer series, this evolved into the 3900 nozzles in a six color single silicon chip in 2006, the Scalable Printhead Technology (SPT).
At present, TIJ and PIJ DOD printers both dominate the technology landscape when it comes to printing.

But the initial advantages of TIJ over PIJ have been leveled over the years by further development of the PIJ technology.

Moreover, a fundamental strength of the PIJ technology is its ability to deposit a wide variety of materials on various substrates in well-defined patterns.

Recently many other applications than printing onto paper have emerged.

In the display market, for example, inkjet technology is used to manufacture Flat Panel Displays (FDP), Liquid Crystal Displays (LCD), color filters (a part of LCDs), Polymer Light Emitting Diodes (PLED), and flexible displays.

The accompanying performance criteria are among the major driving forces behind much research and development efforts.

Within the chemical market, the inkjet technology is mainly used as tool for research purposes. The unique capacity of the technology in dispensing small doses of liquids makes it very useful for this market.

Applications include material and substrate developments as well as coating purposes.

In the electronic market, inkjet printheads are used to create functional electrical tracks using conductive fluids on both rigid and flexible substrates.

One of the first applications of inkjet technology within this field was that for the production of Printed Circuit Boards (PCB).

Other applications include the fabrication of electric components and circuits such as Radio Frequency Identification (RFID) tags, wearable electronics, solar cells, fuel cells, and batteries.

Challenges for the inkjet technology within this field include the ink absorption and the required guarantees of continuity of the jetted lines.

Three-dimensional mechanical printing claims the inkjet technology as tool for rapid prototyping (3D printing), small volume production, and the production of small sensors. Jetting of UV-curable optical polymers is a key technology for the cost-effective production of micro-lenses.

These tiny lenses are used in devices from fiber optic collimators to medical systems.

The ability of inkjet technology to precisely jet spheres in variable, but consistent, drop size, provides opportunities for the cost reduction of existing optical components and innovative new designs.

The life science market is rapidly expanding with new requirements for accurate dispensing of DNA and protein substances.

The high cost of these fluids makes inkjet technology with its precision placement and tight flow control an excellent dispensing tool.

Applications already include the use for DNA research, various medical purposes such as dosing of drugs, and food science.

A rather futuristic application is the use of inkjet printing for the fabrication of living tissues.

The analytic framework combining Technology and Applications is relevant to evaluate at any « M » moment the potential of a technology.

Besides, the detailed understanding of a given technology enables to anticipate, for a specific application, the potential and its limits as far as performance is concerned, of one or another technological branch.

The text above is giving clues about the non-linearity of evolutions in technology.

Along with the following chapter, it shows that complexity is easily explaining some common confusion in the way technology is described. Correlative biases then appear in the "theories" about inkjet capabilities and performance.

1.3 Printing principles / Fluid jetting SCIENTIFIC principles

As far as performance is concerned, the graphic and coding printing applications require some specific criteria to be met.

For an inkjet printhead, an important set of requirements is related to the resulting drop properties, namely:

• Drop-speed: the resulting droplets must have certain speed, typically several m/s.

A high drop speed results in a short time of flight.

The sensitivity for disturbing influences due to variations in the printhead-substrate distance will be less, thus the dot position errors will be limited.

• Drop-volume: depending on the application under consideration, the performance requirement concerning volume typically varies from 2 to 32 picoliter droplets.

Some applications imply that the drop-size has to be changed during operation.

For example, when large areas of substrate are to be covered: Large drops are then useful. On the contrary, when high resolution printing is needed, small drops are the solution.

This kind of conditions is referred to as drop-size modulation.

• Volume consistency: the variations in drop volume (and speed) must stay within a certain band percentage, typically around 2 percent.

This to avoid irregularities on the print.

• Drop-shape: the shape of the dots on a substrate is negatively influenced by the formation of tails or satellite drops.

These are highly undesirable for quality printing.

• Jet straightness: the droplets have to be ejected following a straight line towards the substrate, typically within a range of 10 mrad accuracy.

This calculation applies at the verge of the nozzle.

The further the targeted substrate, the lesser the accuracy (hence the quality) of the print.

That implies the head / substrate distance as a **critical factor** in most printing applications.

- Jetting process:

Productivity and stability are key requirements, which are closely related to the jetting process.

The productivity of an inkjet printhead is mainly determined by the jetting frequency. The frequency is defined as the number of drops a channel jets within a certain timeframe **fdod**, and by the number of nozzles **Nnoz**, defined itself, on one side, by the integration density or nozzles per inch and, on the other side, the printhead's width.

A high integration density brings *many consequences on the functionalities* and on the productivity as a whole.

The **firing power** Pjet of a printhead is the key number to measure the productivity of an ink jet printer. It gives the productivity in m2/s from the formula:

$$P_{jet} = \frac{N_{noz} \int dod}{dpi^2} \times (25.4 \times 10^{-3})^2$$

dpi stands for the number of dots per inch.

Equation 2 – Firing power calculation for a printhead

NB: The above equation is valid when considering *single pass* applications!

This results in a print time (**t_{print}**) for a specific area (**A_{print}**) to be printed:

$$t_{print} = \frac{A_{print}}{\eta P_{jet}}$$

with η the efficiency of the printer, which plays a very important role when considering *scanning systems*.

Equation 3 – Ratio enabling to evaluate printing time

For most inkjet printers are standing alone and using a carriage moving the printhead(s) over the full width of the substrate.

Between each stroke of the carriage, or print swath, the paper / substrate is translated over a certain distance enabling step by step to cover the full targeted area.

Beyond a certain frequency level, the carriage turn-time and the substrate step give more and more limitations.

These limitations indicate an optimum DOD-frequency. So, as far as scanning printer systems' productivity is concerned, the *marketing efficiency* of printing will thus be dependent on the frequency / speed ratio, or drop volume.

In other words: Frequency / Speed and/or Frequency / Volume have to be optimized for business performance!

Frequency enables to cope with fast moving substrates when jetting speed conditions the accuracy of the drop positioning.

On the other hand, frequency brings density and then definition ("quality") but the drop size (volume) is fundamental to get contrast (bigger dots = better contrast).

This leads to consider the maximum applicable DOD-frequency which, by instance, amounts for 600 dpi prints in most scanning printer concepts to: 30 – 40 kHz (cf. e.g. Fig. below).

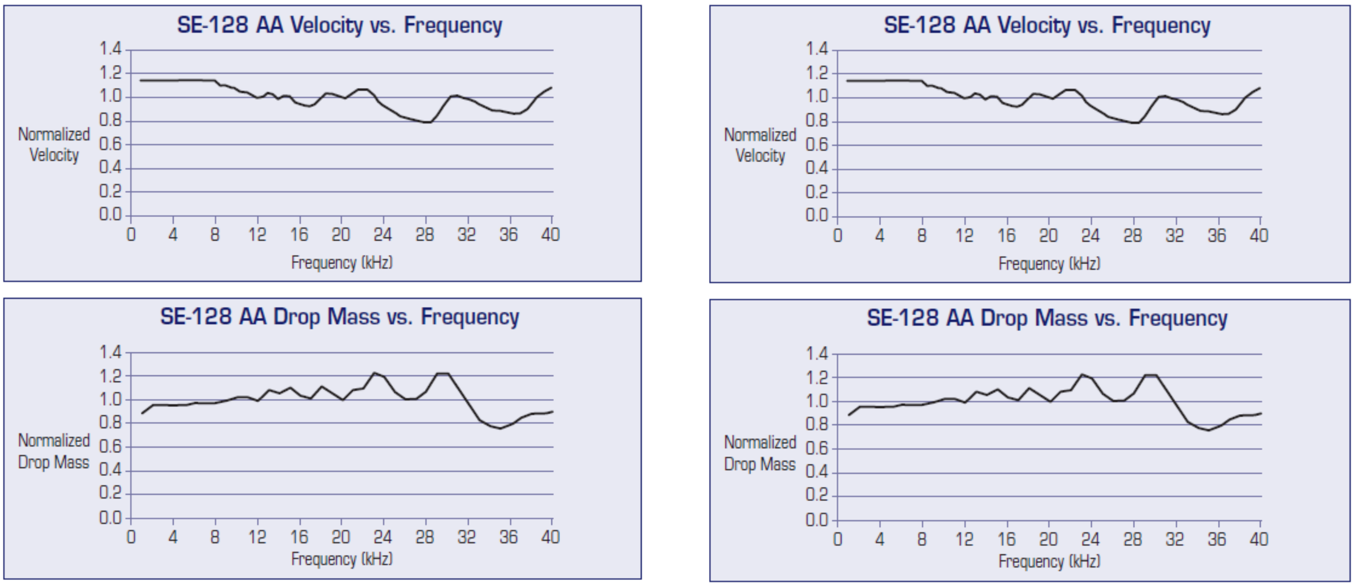


Fig. 16 Jetting Characteristics of 2 DOD heads (Source: Spectra)

High productivity single pass printing requires something like a page-wide array with thousands of nozzles as explored by Spectra and Brother-Kyocera, and used by Xerox/Tektronix in their Phaser printer series.

Another way to increase productivity is to use several nozzles per channel as explored by Trident[1].

- Printcost and quality

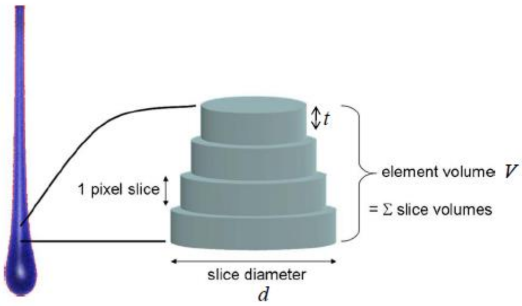
The number of dots per inch is important for print cost and print quality.

Print cost is directly related to the thickness of the ink layer or amount of ink/m2.

As a first order approximation, the required drop volume for a 600 dpi resolution is about 32 pl and for a 1200 dpi resolution about 4 pl, since volume scales as the third power of the spatial resolution.

If we know that the cubic power is a good regular approximation of the volume, we also understand that the porosity of the targeted substrate must be considered.

[11] One piezo for several nozzles. Up to 4 nozzles per piezo.



$$V = \sum_n \tfrac{1}{4} \pi d_n^2 t$$

Fig. 17 Size drop calculation

This is the approximation commonly used to evaluate the size of a drop during the jetting process:

$$V = \sum_n \tfrac{1}{4} \pi d_n^2 t$$

Equation 4 – Formula to evaluate size drop

But make no mistake: the reality of the mass of a drop can very fast derive from the approximation (satellites…) with major consequences on the print quality!

Print quality is better with smaller dots at a high resolution. Finer details can be represented and the graininess of the print is far less with small dots.

For water based inks the less amount of ink in smaller drops enables shorter drying times, another argument in favor of smaller drops.

So there is a challenge to combine productivity and print quality/cost. It often results in a trade-off.

But drop size modulation is a way to meet both requirements. The small drops are used for achieving a high print quality and the large drops for productivity.

Along with productivity, the stability of the jetting process is one of the most important performance requirements for inkjet printheads as a whole.

Typically, it is accepted that at most one failure occurs per a certain number of jetted drops.

For printing onto paper this figure is one billion, but in some industrial applications, the standard can be still more demanding.

In addition, more general requirements include the lifespan of the printhead (typically more than ten billion actuations per channel, a fundamental strength of PIJ over TIJ), the materials compatibility (variety of inks that can be jetted - again a strength of PIJ over TIJ), the maintainability, and the production cost of the printhead (a weakness of PIJ).

1.4 Micro-fluidics: The second Gutemberg revolution (disruption) and its consequences on companies' performance

In this part:

1- We conclude on how complex the Taxonomy of a technology like ink jet is.

2- We show that the evolution of this technology did not follow the model of a "Scale", but that of a "Bush" (Gould, The Full House, 1996).

3- We then suggest that there are disruptions in such an evolution, non-linearities, crossings and dead ends.

1.4.1 How complex is the taxonomy of inkjet technologies in microfluidics.

For a layperson, someone who is not initiated in it, inkjet is well considered as a technology.

But people cannot imagine that behind the generic technology lie so many different forms or types – sometimes very different between themselves – of the same reference process. What we suggested in the previous parts.

1.4.1.1 *The Satellite and the Ant:*

Where are we looking at it from?

To see the total complexity of the connections between the various existing sub-technologies appear, we need to look « close up », beyond the single DOD / CIJ opposition.

Yet, for ink jet, most of the research work is confined to looking at the difference between these 2 large families, DOD and CIJ.

In other words, research usually just considers the first level of what is a much richer arborescence, as we will explain it in more details.

It's as if, as a general rule, we were tacitly used to looking at reality from a Satellite.

Such a height can result in confusing a sandy beach for one with pebbles!

This is a confusion that cannot occur when we go down to the same level as an Ant moving forward. Our Ant is at the right level to have instant knowledge about the type and variety of the ground it is crossing.

Yet, the conventional representation of fluid projection technologies (see below Fig. 18) is shown in 2 or 3 layers only. This means very much «looking down » from far above which can lead to confusion or errors that we will precise all along the dissertation.[7]

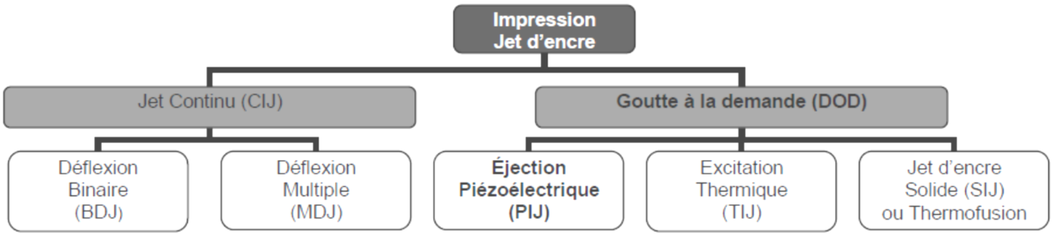


Fig. 18 Projection technologies (source: S. Poirier, INPT 2009 p. 24 [2])

1.4.1.2 *Approximate representations.*

- Representations and technology trees can be far more complex than the one previously exposed. E.g., see below a technology branch based on10 layers (see also p. 104 and Fig. 477)

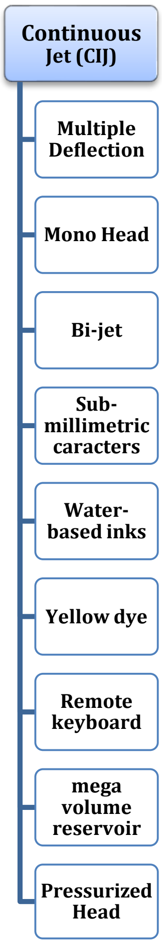


Fig. 19 A technology in 10 layers

[2] Thermofusion refers to a piezo technique.

The danger of excessive simplification is that it could lead to the denial (often unintentional) of a basic scientific principle by mistaking absence of evidence (of other « branches ») for evidence of absence.

Even when the representation is limited to a few layers, differences appear according to the articles and the dissertations

Let's compare:

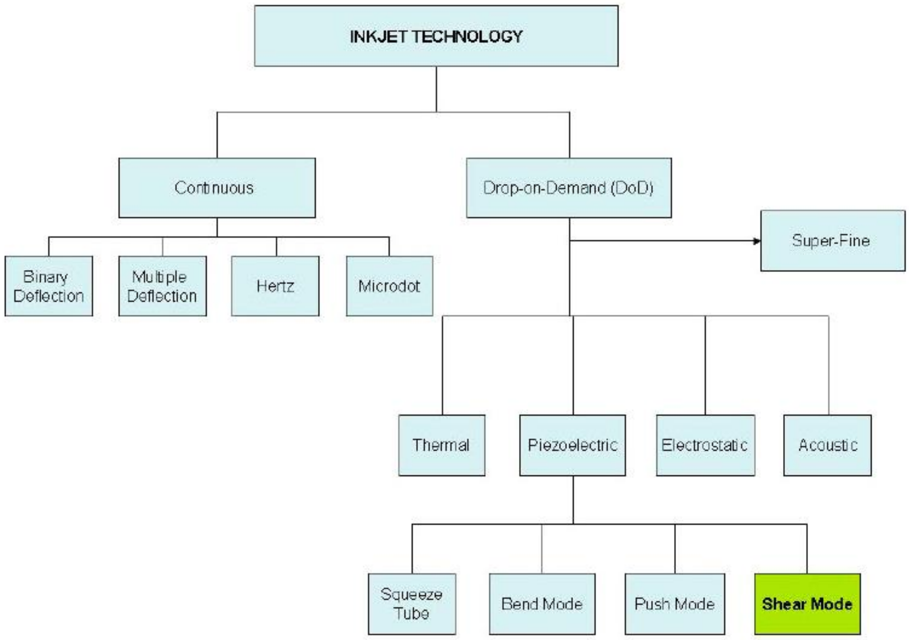


Fig. 20 Projection technologies (source: U. Caglar, Tampere University of Technology, 2009, Publication 863, p. 13): [8]

To:

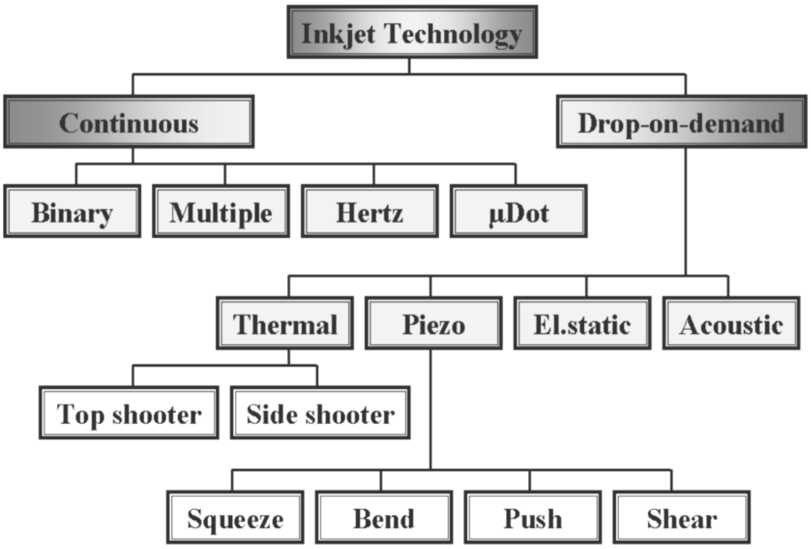


Fig. 21 Classification of inkjet printing technologies, (adapted from H.P. Le: Progress and trends in ink-jet printing technology, Imaging Sci. & Technol. 42, 49 -1998).

We notice that the above scheme:

- Does not display the valv jet version of ink jet technology.
- Exposes a kind of incoherence in showing “Binary” and “Multiple” aside “Hertz” systems. For Binary and Multiple are also hertzian processing solutions.

So let’s compare now various other representations, including the one already used at the beginning of the present chapter:

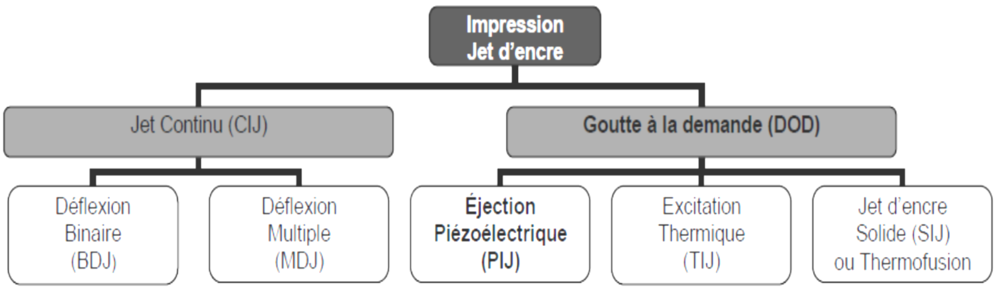


Fig. 22 Projection technologies (Source : S. Poirier, INPT 2009 , p. 24)

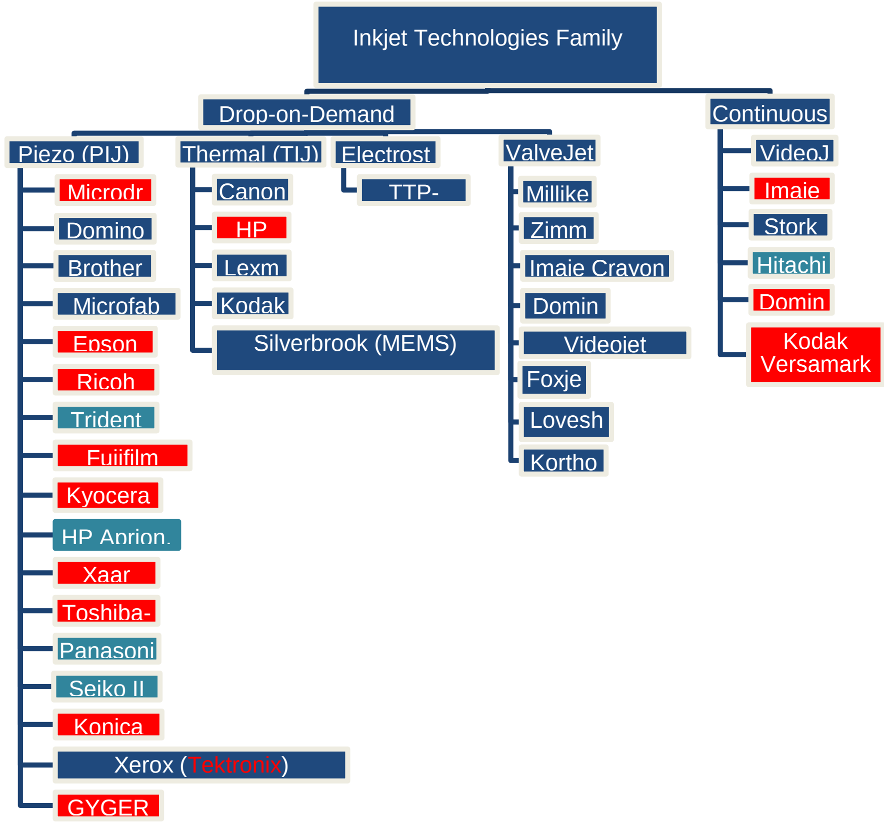


Fig. 23 Branches and Brands in inkjet (Pagora 2012)

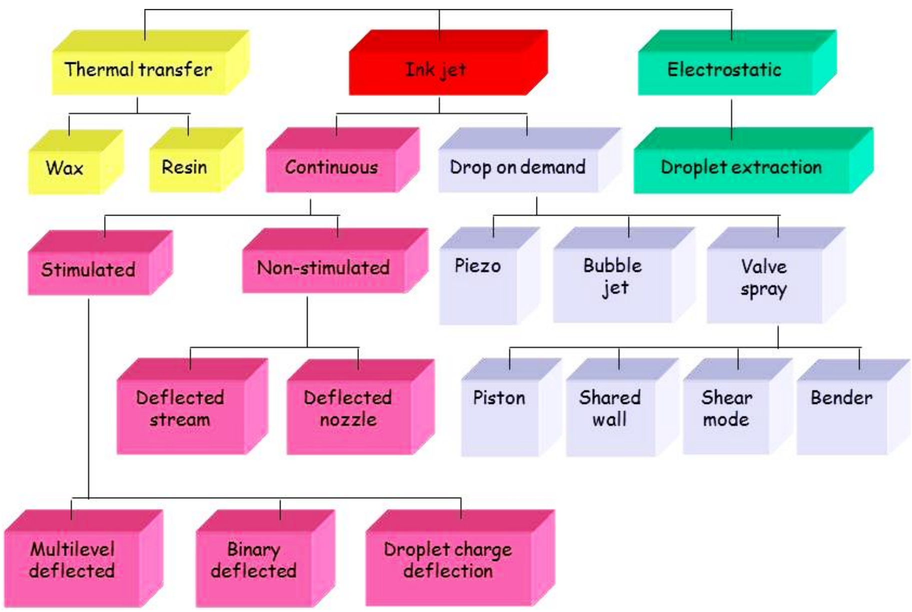


Fig. 24 Ink Jet Technologies (source : P Pierron / Dickson 2011).[9]

Not only, as we have just pointed out, are there clearly differences in the representations but we also note that these representations are incomplete. Indeed, most of the schemes for example « forget » the valve jet in DOD, the main branch. And this despite the fact that the valve jet is a technology that applies worldwide and in so many manufacturing plants!

Obviously representations are well incomplete because none of them can include …all the others.

And yet these structures come from prominent experts and some very good PHD dissertations.

But this state of affairs no longer comes as a surprise when one considers that in their various pieces of work, the authors draw on the same model (each time with a slight « deterioration » linked to their own individual "business objective") , and even (for the least interesting pieces of work that we have not retained) copy /paste.

Finally, and this was very much the case in the experts' interviews that we have conducted, we note a natural tendency towards linearity!

This is shown in 2 ways (complementary):

- The representations are simplified (some branches are disregarded and the crossings do not appear).
- The representations take the form of "scales".

In one particular case: when an expert was consulted, his spontaneous representation turned out to be so rich that he seemed to be overcome by his own knowledge and the work of architecture had to be interrupted because the complexity was giving rise to incoherencies (all sorts of erasures and alterations).

Very complex, but so rich, representations are what we call, after Gould, « Bushiness ». They show by themselves the result of various dynamics (e.g. technological dynamics). All dynamics which would remain invisible instead. As Edward Coke expresses it, followed by Liné: «*Nomina si nescis, perit cognitio rerum* ».

1.4.2 Bushiness vs Linearity

1.4.2.1 ***Dominant representation and variation***

The « bush » seems to be a better representation of the genealogy of a technology than the « scale ».

A "photograph" of the type of technological representation shown in the Dickson / Pierron tree above (Fig. 24), conceals the complexity of the evolution. The « bushiness » comes from technology/brand (companies) mixing.

Each company in the sector is in fact contributing to the diversity of the system through its very own differentiation strategies.

From an epistemological perspective, this is somewhat reminiscent of biology and naturalism. For Linnaeus (Sytema naturae, 1735), a scientific Fixist, the prioritization of the classifications by class, genus, order, species and strain contributed a definitive framework, linear to perfection. However, since then, the combinations, interpretations and even the idea of evolution have made this diagram much more complex and bushy

But even if the technological complexity is comparable in a number of aspects to that found in biology, the comparison needs nonetheless to be kept in perspective.

In fact**,** what would correspond to « the species or the strain » in technological terms is not the technology or the sub-technology, but the particular **use** of the technology for a specific application. This also makes it possible to differentiate between application and use.

Furthermore it enables us to demonstrate just how rich the system is: the condition of the microfluidics would therefore be established not on the sole basis of the technologies used to construct the ink jet *heads*, but on the uses employed by the companies and brands of this component by combining it with fluids (all sorts of inks) and other equipment to provide solutions for applications that give real meaning to a technology..

Moreover, the technological agreements concluded by brands add an additional layer of complexity. Indeed, a brand can be the owner of a technology, the exclusive user of a technology or the co-user of a technology.

But today the head alone (its technical principle) is defining the technology as a whole!

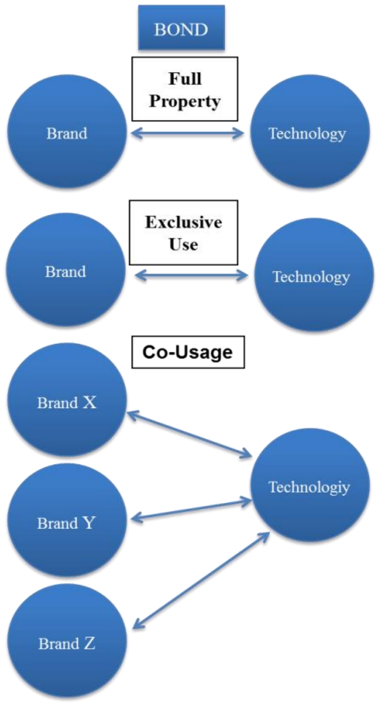


Fig. 25 3 various agreements about Intellectual Property

The potential agreements between brands, taken from the diagram above, will generate technological hybridizations according to the applications that each company aims at. Yet, companies can create and develop projects at any time. It is therefore very difficult or even impossible to completely represent the true state of a technology.

In addition, partnership links evolve over time. Brands are performative (within the meaning of Michel Callon (1986) and Bruno Latour (1995)), performative in their environment: their actions on the markets, the competitive game, and the technological developments result in «new deals » and conditions.

The complexity of these dynamics is not reflected by the « crystallization » at a given moment « M » of the state of the technologies in an espaliered arborescence, in the form of a « scale ».

Idem for the arborescence related to the various brands supporting these technologies (see Giraud's scheme above).

We are aware, of course, that any schematization is simplistic.

Nonetheless, we feel that in the context of this exploratory piece of work, a linear vision of technological evolution may be overly distorted. This therefore explains, in part, some surprising failures in terms of both radical and incremental innovation (some parameters overlooked because they were invisible!). Likewise, this type of representation conceals all the creative resources that can contribute to the emergence of innovative solutions.

Dominant Representation is in fact based on a logical and chronological **linearity**. We'll come back to this later.
This linear vision of innovation therefore results in **underestimating the complexity of technological evolutions**.

By underestimating the complexity of the evolutions (socio-technical: i.e. both relational and technical), some parameters come to be arbitrarily overlooked in the story as it unfolded.

Overlooking these types of parameters leads to underestimating the degree of uncertainty associated with technological evolutions and their related innovation.

By underestimating the degree of uncertainty associated with innovation, the most obvious parameters are overestimated.

At this point the risk of failure (for a startup) is heightened by a two-fold exposure mechanism:

- Development of weaknesses: Development of weaknesses linked to the feeling of control associated with the identification of one section of the parameters. False perception of being in control of the situation. Overestimation of the real control. Because the number of parameters (or their combinations) are underestimated. Or because the importance of the identified parameters is overestimated.

  This is corroborating the so-called *Overconfidence Effect* (D. Kanhneman, 2012).

  It appears when we are not prepared for the risk. Or rather we're so often only partially prepared for its appearance. To the extent that some **circumstances** have been **forgotten**.

- Over-exposure to the risk linked to the underestimation of **the frequency of occurrence** of elements that are not controlled. Since there are elements of uncertainty that have been overlooked, the perceived « volatility » is lower. The probability of exposure to risk is therefore higher than either expected or even calculated (for some particularly well documented innovation projects).

Again, Dominant Representation is rightly based on a logical and chronological **linearity** as we will clearly demonstrate by resuming technology history.[10]
Then, with the example of the CIJ/SCP technological development, we show how uncertainty can be underestimated, when key parameters are neglected.

All this is based on the advent of CIJ applied to SCP, which is well a meaningful part in the great history of inkjet.

And we intend to have a kind of zoom effect on the heydays of the CIJ branch of inkjet, leading to consider that the single linearity exposed before (historical overview of inkjet technology) does not explain by itself the success of CIJ/SCP.

So let's expose the 3 clusters having generated CIJ's development at the worldwide scale:

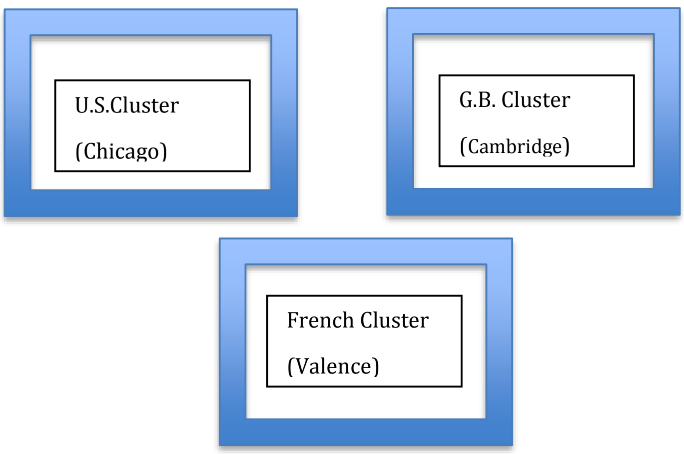


Fig. 26 Scheme of a priori independence between the 3 CIJ clusters.

This representation only aims at imaging the absence of an assumed direct link between the 3 identified technical sources.

The next section of our work will demonstrate the oversimplification of this view.[11]

Indeed, in the following section of the thesis we establish the relations between these clusters from the very beginning.

Yet, these a priori imperceptible links are similar to invisible, neglected parameters, without which proven success would not have been certain.

Simply being satisfied with linear representations is to underestimate the variations surrounding the central tendency.

Yet when one considers the reference sequence in life sciences, the « variation » is the first element taken into account:

Variation/ Selection / Evolution.

Underestimate the variation and one cuts off the lines of evolution.

Because variation ***determines*** evolution!

Therefore, we connect variation with non-linearity (any form of hybridization, impasse, cross-fertilization or unforeseen circumstance…).

1.4.2.2 *Linearity and variations*

Genuine changes in central tendency are meaningful, but our failure to consider variation (Gould, *The Full House*, p.57) has led to a backwards interpretation: the evolution of ink jet.

Step 1

When we ask experts to represent the evolution of ink jet products or ink jet technologies, all the branches, all specimens of products are drawn at the same size.

The evolution is presented in a systematic linear and progressive way leading to the latest technological developments. From the various stages of development are emerging trends.

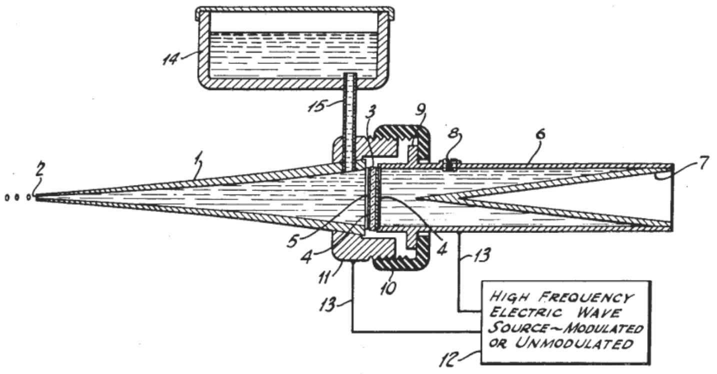
And in some legitimate though limited sense, these trends are true.

Step 2- So far, so good!

But (as I shall show) so very limited, and so misleading…

The lineage, for example, of the first drop-on-demand piezo inkjet device patented in 1950 to advanced piezo DOD represent only 1 pathway through a very elaborate bush of evolution that waxed and waned in a remarkably complex pattern through the last 50 more years.

50 years of evolution of DOD heads: FROM[3]



TO

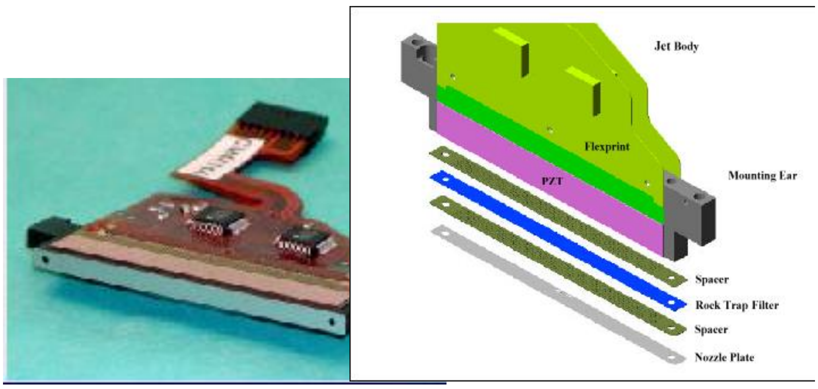


Fig. 27 Siphon recorder (above) and Spectra SL 128 (Courtesy of Pagora 2012).

This particular pathway cannot be interpreted as a summary of the bush; or as an epitome of the larger story; or, in any legitimate sense, as a central tendency in ink jet evolution.

We have chosen this sample of a totality for one reason alone: DOD piezo is the currently dominant genus of ink jet, and therefore easy and logic to use as an endpoint for a series. If you are committed to depicting the evolution of any group as a single pathway from origin to a current kind of glory, then one can suppose that the story must be told in this conventional way. But when we consider more comprehensive models of evolution, we must call such pictures into question.

We therefore arrive to the subject of **ladders versus bushes** (Gould, The Full House p. 82); or, in the context of this thesis, individual pathways chosen with prejudice versus entire systems and their complex variations.

As the Bible says about wisdom, so too may we state about the proper iconography of evolution: “She is a tree of life to them that lay hold upon her.”

[3] Drawing of the first drop-on-demand piezo inkjet device /US Patent 2,512,743 (in H. Wijshoff: Fluid Dynamics in piezo inkjet heads, 2008. A piezoelectric disc (5) generates pressure waves in a solid cone (1), causing a spray of ink drops from the nozzle (2)).

Evolution rarely – that is true in biology seen as a model of any other form of evolutionary process - proceeds by the transformation of a single population from one stage to the next.

Such an evolutionary style, technically called “anagesis”, would permit a ladder, a chain, or some similar metaphor of linearity to serve as a proper icon of change. Instead, evolution proceeds by an elaborate and complex series of branching events, or episodes of speciation (technically called “cladogenesis” or branch-making).

A trend is not a march along a path, but a complex series of transfers, or side steps, from one event of speciation to another.

The evolution bush of ink jet includes many terminal tips, and each leads back to *the effects of static electricity on a drop stream* (in 1749!), through a labyrinth of branching events.

No route to the origin of ink jet is straight, and none of the labyrinthine paths has any special claim to centrality. (only refer to the various and already very simplified figures exposed before).

We run a steamroller right over a fascinatingly complex terrain when we follow the iconographic convention for displaying the pathway from Abbé Nollet origin (1749) to piezo DOD as a straight line.

Evolution to us is generally a linear series of devices getting smarter, more powerful, or at least better adapted to local environments.

Our bias against considering the variation of full systems leads us to designate preferred pathways. And these are most of the time trees pruned to single twigs.

But rather than bringing forth our conceptual steamroller to straighten the preferred path, we should first recognize **the primacy of variation within complex systems**, and the derivative nature of abstractions or exemplars chosen to represent this varied totality.

Fig. 28: Flatbed printer. Variation within PIJ technology (Courtesy of Ardeje 2009)

Fig. 29: Roll to Roll printer. Variation within PIJ technology (Courtesy of Ardeje 2009)

We do not deny the factuality of the conventional pathways. But we do wish to demonstrate what a distorted view it provides when we depict the evolution towards the dominant design as the essence of the history of ink jet, and then ignore the variation supplied by a myriad of other pathways in the full house of the microfluidics bush.

To further discuss about Technological Trajectories (Von Hippel, AOM 2012), we then consider the evolution of ink jet as promoted by Asaba (see pp. 98 to.100 too).

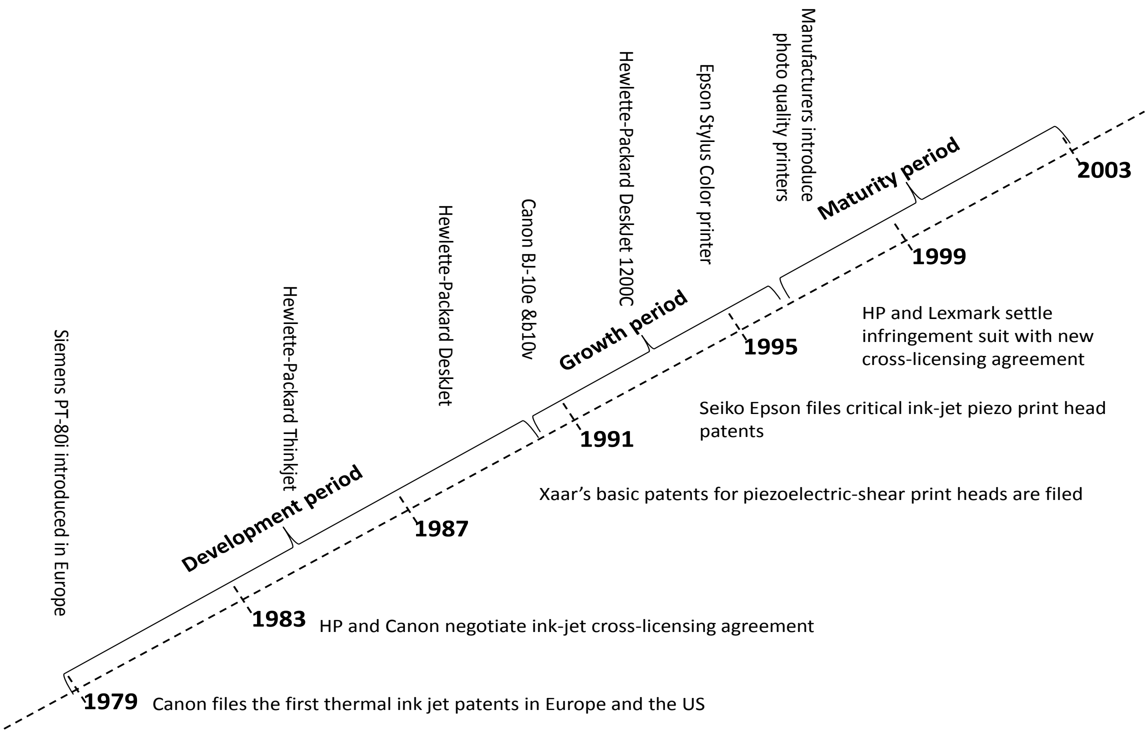


Fig. 30 Three time periods of technological and market development in the ink-jet printer industry, Clymer and Asaba 2008 p.140.

This above tree is used in many articles as a reference.

As far as the period between 1987 and 1991 is concerned, the depiction highlights 3 major events in the world of ink jet:

- The launching of the HP Deskjet. It was to become, among DOD technologies, a kind of « model T » in printing.
- The Xaar patents relatively to piezo électric heads in shear mode.
- And the ramp up of the Bubble Jet 10e and 10v by Canon.

This is undoubtedly true.

But it does not do justice to the huge number of branching events that occurred in ink jet technology as a whole during the period considered.

Just to mention a very limited list of these events and for the single CIJ branch:

- New printing heads and printers enabling to print more than 2 lines!
- Launching of the revolutionary (14 patents) S7 series by Imaje.
- First trials for a full colour CIJ jet arrays (large format).
- Launching of Elmjet binary technology.
- New releases of devices using edible inks.
- Main players delivering systems using invisible fluids.
- Launching of printers to mark submillimetric data.
- .....

Such points indirectly demonstrate Teece's argument (1986) that value can be appropriated by (essentials) complementors. In this case the complementors are ink and specific prints modules (mainly heads) mostly.

Combining "Core Modules" with "Optional Modules" enables to optimize the application fit.

1.4.2.3 *Point 1: Linear technology trees hide the complexity of disruption processes.*

To understand the whole complexity of technological disruptions, we should consider illustrating technological evolutions in the shape of a "Bush".

All the more since disruptions in bulk do not appear at a generic level of the technologies but at application level.

The latest developments above enable to precise the bond between *"linearities"* in the history of ink jet and the main theme of the dissertation.

Why is the "bushy" approach of technological developments contributive to the thesis work?

For the « bush » leads to consider and reveals the complexity.

Only the understanding of elements in details in the complex bushy process make it possible to explain very different degrees in technological and business performances.

The reasoning is the following:

- It is more complex than it appears to be.

- Technological evolutions are linked to the applications progressively covered, and not to a kind of technological dynamics only. So a kind of “Darwinian” process is operating (through technological mutations); but also a Lamarckian process as far as we take into account a better adaptation to market evolutions of **some** specific technological branches.

- A linear approach is enough to explain the performance of a whole sector. But it is insufficient to explain micro economical differences (at firm scale) for a given application.

Thus 2 technological branches very near from each other (e.g. both belonging to DOD) can perform very differently for a same application.

1.4.2.4 *Point 2: Good understanding of scientific principles is leading to good understanding of performance*

(the reverse is true)!

In the framework of a disruptive application, when one wants to explain the performance level of a company, one should first show the coherence between the technological *variant* used with the application.

In a nutshell:

- Scientific principles’ understanding of the technology used enable to explain the performance for a specific application of this technology.
- The generic technology is not enough to explain the performance. We have to specify the application and the “sub-technology choice”.
- Disruption is more or less complete according to the specific sub-tech used.

Many future works could derive from the previous statements as:

- Showing that authors suggest in many articles to relating companies’ success to disruptive technology (Garnsey 2009, p. 8) and that this linkage is repeatedly FALSE!

- Or checking if the disruption relates to market expectations, technology innovation or Business Model disruption.

Chapter 2 - PERFORMANCE OF SPINOFFS IN MICRO-FLUIDICS: THE 2 EUROPEAN COMMERCIAL INK JET CLUSTERS

Evolution of the research topic:

The initial question at the beginning of the PHD process was to evaluate if innovative companies were more crisis-resistant than others.

With complementary questions such as: is performance a question of sector or is it a question of company?

We intended to apply the research topic to the field of microfluidics were we had a quite unique access to valid data.

We then conducted a broad literature review about performance, on evolutionary theories and also on the microfluidic systems' evolution from a scientific standpoint.

This led us to consider the bond between disruption and performance.

This also led us to limit the field of investigation. So we decided to study the disruption in the framework of spinoffs from the same anchor (Tucci 2009. *Spinouts from anchors and their role in knowledge dispersion*).

At last, we pointed out that, as far as microfluidics was concerned, a lot had been already written on a microfluidic cluster of companies - with the same mother - located in England in the Cambridgeshire.

By comparing what was written on this cluster and the reality of the technology studied, we were brought to state that the reasons underpinning spinoffs' performance could be questioned and revisited.

We thus agree with what C. Christensen had recently established about disruption and the "Need of a Theory" to offer to managers how to measure (AOM 2012, paper 1439).

We are indeed aware that in innovation, most of the time there is no more money to go to adultery. And that innovation does not help to "manufacture" the figures managers are expecting.

So one big question is arising through the issues of work charts and metrics – what are the rules in a company that design this company? – through the issue of innovation budget – how do you budget innovation when it is destroying short term profit?

This "big" question is: How can we measure profitability?

To enhance our study, we adopted a twofold logic:

- Technology
- Actors

Technology and its evolution over time were like a common thread that we followed all along our research. And in parallel we were interested in the logic of actors (companies) exploiting and exploring this technology possibilities.

2.1 Methodology: Framework

On this basis, we developed the following methodological hints:

To continue, following the Technology / Actors pattern, and as we demonstrated it in the introductive part of chapter 1: The sector of digital printing as a whole developed fast. But how did this overall growth reflected at company-scale? To analyze in detail this evolution, we have chosen a technological branch represented by 2 clusters in Europe.
On this well-defined basis of knowledge, we have then implemented the forthcoming methodological landmarks:

2.1.1 Literature review

The references issued from the literature review are permanent along the whole text and adapted to the thesis evolution and process.

As appearing in the bibliography, the literature review is extensive and diverse according to the progress of our findings all along our work. For sure multiple signs of nonlinearity can be found at this level too.

This complexity and the number of different fields exposed in the bibliography are explaining why we made the choice to refer constantly to the literature rather than just positioning a literature review formal analysis restricted to the methodology chapter.

2.1.2 Convergence of Evidence (case studies)

To analyze the companies in the chosen clusters, the set of sources exposed in Fig. 31 was used:

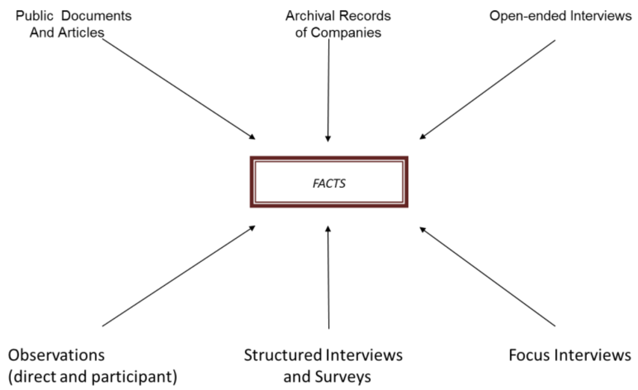


Fig. 31. Sources of information about the ink jet clusters.

2.1.3 A Fractal Approach

A fractal approach: In a sense, in all that we develop in this text, and as already mentioned earlier, we devote ourselves to the analysis of "islets" in market and technological terms.

Indeed, we do not consider micro-fluidics as a whole, but rather as a very complex combination of multiple innovative paths.

And you have small and large paths: and on each path, small or large, we find leaders that are not attracted by niches.

But on each path, some SMEs have a strategic behavior consisting of monitoring the market place for *niches that industry leaders might have missed* (Miller, A. (1988) Taxonomy of technological settings, pp. 239-254). Or "sub-markets" that do not fit with their profitability constraints (fractal approach).

Hence a proposition to explain the superior performance of innovating firms in times of crisis: The most innovative SMEs are better crisis-resistant for their "profitability pockets" (their "applications" within the meaning of C. Freeman) are less open to leaders:
Less open because, by being innovative, they have built a competitive advantage on these specific pockets.
So, on a segment taken by a non-innovative company, the incumbent only needs to review its profitability scale to become competitive (fractal approach).

On the contrary, on a pocket occupied by an innovative company, this same leader is obliged to create (it does not pre-exist), a specific value proposition (entry barrier).
A hyper-adapted value proposition is indeed the very translation of a competitive advantage.
It is somewhat reminiscent of a botanical experiment on adaptation phenomena. This survey conducted in the Montpellier region (France) is showing that plants living in small holes on concrete esplanades have heavier seeds as the ones living in open fields. They have a very high relative efficiency on these very specific spaces.

To go back to the process of this work and the choices enacted in the framework of the dissertation, in terms of method and topics: If *performance* appeared slowly but surely as the dominant theme, the theoretical framework was long to emerge.
We have tried various question re-statements:

- What makes the variance in performance for SMEs as far as the crisis is concerned?
- Is the performance of an SME related to its innovation capabilities?
- Are the most innovative companies the ones resisting most?

What was recurrent in our research was our feeling of frustration when reading taxonomies considered as explicative (Cooper model (1991), model of Reynolds (1993), model of Davidsson (1991), Birley and Westhead's model (1990). Cf. Bibliography).

For these models were intending to apply in mass to all kinds of companies. But the reality of SMEs appeared diverse enough to be sensitive to specific factors, like the size effect just to mention this obvious one.

That was leading us to consider that research on performance in this context, should probably systematically refer to a well-defined layer of markets.

It would imply a kind of "quantum mechanical" specifically adapted to SMEs and small businesses. We introduce reference to quantum mechanical for the work at the level of very small companies could invalidate for SMEs rules universally accepted for big companies!

Then, the capability for an SME to build its own level of innovation would become a guarantee of performance.

More generally, this standpoint was raising questions on this huge set of companies, invisible at some scale, but that take well their part in the overall movement of innovation.

Hence an issue to understand if and how, this matter of scale had consequences on taxonomies.

2.1.4 Data collection and interviews.

- We have collected the primary data through interviews of managers and reading of reports and dissertation thesis on microfluidics technology.

- We have completed this set of information by open-ended and focus interviews with experts.
- The experts were identified using a Snowball method for sampling (Biernacki and Waldorf, 1981).
- The general framework of the survey was based on a qualitative multiple case study.

The methodology and the case characteristics (Table) including "special features" are detailed p. 63 and after.

At this stage, we would like to notice that all along the preparation work, we have tried to *avoid concentrating on* the organization of data more than on the analysis effort by itself.

Having been trained and having used an "In Vivo" type software, the risk of fetishizing the coding process was quite clear in our mind.

2.1.5 Theoretical framework

We subscribe to the idea that *markets are not perfect.* We do agree to consider that Supply does not equal Demand (and not only in quantitative terms).

That leads to consider the heterogeneity of markets.

2.1.5.1 ***Homogeneity vs heterogeneity***

This heterogeneity of markets reveals a kind of granularity, various levels of reality that are invisible at some level. A "fractal approach" (Mandelbroot, 1997) is then appropriate to evaluate the right level of understanding.

2.1.5.2 ***Fractal approach again***

We have considered homogeneity analysis and heterogeneity analysis as two complementary methods: What is common to companies in the same cluster (homogeneity) and what makes these companies different (heterogeneity).

The fractal approach is the method enabling to consider not only the most general level of a technology (genesis technology), but also its various branches related to specific applications and markets.

2.1.5.3 ***Data sources***

Primary data:
We have conducted interviews in firms: With executives and entrepreneurs.
We have also conducted interviews with scientists (physicists and mathematicians mainly).

Secondary data:
They have been extracted from patents, publications and background information on firms.

2.1.5.4 ***Single industry research***

It is a single industry research. And this is something that makes this dissertation distinctive, for all the companies surveyed are belonging to the same digital microfluidic sector.

2.1.5.5 ***Performance***

We choose first Turnover and Headcount as appropriate metrics for Performance.

Why?

We know that many parameters have been mentioned and used by scholars to measure Performance.

Generally speaking, there are 4 various ways to tackle with this topic. Most of the time they are combined:

- One way is to consider the performance in relationship with the *environment* of the firm.
- Another approach considers the role of the *entrepreneur*.
- One prospect is focusing on the *key-processes* enabling the company to perform.
- Many authors are also scanning the *initial characteristics* of the venture to infer the performance.

But we want here to underline a managerial approach in which *Turnover* is the root-metric of all others measurement variables.

Indeed, any operational result in a company (Birley & Westhead 1994), net profit (Cooper 1994), price level (Hall and Fulshaw 1993), market share (O'Farell 1986) is utterly dependent over time, of the evolution of the general turnover.

A company cannot, without exposing itself to great danger, generate on a significant period of time (5 years for example) higher profits, higher amounts of investment, or strong increases of expenses in general, without a significant increase of its turnover meanwhile.

So *productivity* could have been also the appropriate metric, but:

a. Either the company gets a high productivity level at the beginning of the period (early stage of development / ramp up phase). And then it is very difficult to expect still a strong growth afterwards in its resources… *without turnover increase*.

b. Either the productivity of the company was poor in the past. And then, the dynamic to improve productivity can *help to increase the turnover* as well by freeing resources. If this move is purely defensive it will be difficult to consider the link between just cutting cost and company development. As the CEO of Thomson group once said: "It is difficult to become the leader of a market by the only means of cost reduction".

In the case of Headcounts, there is a strong relationship between Turnover evolution and Headcount evolution in a company over time. So we use it as a complementary and a kind of "control" variable.

Besides we tend to consider Headcounts and Turnover evolution as the most obvious and easy-to-get signs of a company evolution.

b – Justification of case-study as the method to be used
Reading several documents on the history of micro-fluidics and the ink jet technology, it appears that all the articles do not tell the same story.

But that is rather common from a sociological and epistemological standpoint.

Nevertheless, the fact that secondary data on the topic are not consistent and homogeneous with the direct collection of evidence among existing and "real" actors brings to question the validity of the story as previously written.

Specifically, and as far as ink jet technology is concerned: It seems that there is a kind of uncoupling between the performance and presumed disruption from a company as shown in the regular articles about spinoffs' performance in ink jet clusters.

2.1.5.6 *A case study strategy of research*

In the case of spinoffs' performance we are not at a stage where the phenomenon could be put under equation!

Referring to the context stipulated above, it is clear that there are TOO many (uncontrollable) variables to consider.

The complexity is coming from the diversity of actors (activity, technology promoted, size, history, reasons for spinning out; just to mention some criteria). The complexity is also coming from the huge number of factors potentially relevant to evaluate the performance in itself.

Beyond the number and nature of data to consider, an additional obstacle to the use of a well-defined metrics is linked to the impossibility to control the data. What weighted score would one apply to evaluate the impact of a change in management (e.g.) for one of the spinoffs surveyed? In the same way: How could we measure accurately the impact of the many technical choices occurring in the very first years of a start-up?

The fact that so many variables to consider are uncontrollable and the complexity of the data to manipulate are both leading to find a method including "direct, detailed observation as a source of evidence" (Yin, 1994:14).

These two sets of causes are the reason why a case-study was appropriate to better understand (verstanden) spinoffs' performance.

2.1.5.7 *Dual methodology (approaches)*

The *qualitative methods* we used in this context relate to organizational ethnography.

They are referring to an empirical approach based on observations.

Interviews and direct participation were used as fundamental means to observe.

What confirms a dual methodology covering to 2 processes in the research:

On one side, method suggests to actively interacting with the actors (workers, managers), so as to create a "shared meaning" (interpretation) of what is going on (link with interpretive research).

On the other side, it implies an ongoing observation of the actors.

The "case" will then later on emerge as the combination/integration of these two approaches.

As far as our convictions are concerned about how to analyze the reality from a socio-technical standpoint, we subscribe to the reaction against a kind of "scientific management" (promoted by the studies of Hawthorne).

That leads to underlying the importance in management of the human, and the social sides.

A scientific approach of managerial and business facts should indeed fully consider the complexity of social phenomena.

This is strengthening the choice for case study as the relevant methodology.

For a case study is a method by which a bounded social phenomenon is accurately described (prepared, illustrated) doing fully justice to its context.

2.1.5.8 *Other considerations about case study writing*

The choice of case study as a method was also based on the following understanding:

- It is descriptive (but not analytical). The analysis follows later. It is not an explanation.
- It is in-depth: "the most complete and detailed sort of presentation of the subject under investigation" (Yin 2003).
- "Analytic generalization" (as opposed to "statistical generalization"): It generalizes a particular set of results to some broader theory.
- Case study is to be used within the context of a phenomenological approach
    - When the boundaries between the phenomenon and the context are not evident.

- When the entity is identifiable (bounded in time and space; e.g., not worldviews).
- When the context (social, political, cultural, etc.) plays a role.
- When there are real-world situations.
- When there are many (uncontrollable) variables (in the context).
- When there are many sources.
- When "how" and "why" questions are asked.

The dissertation is also taking into account the constraints to make the case study methodology valid:

- There is a need for some prior (independent, external) theoretical framework to guide data collection (and later analysis). What we had with the framework of the disruption and evolutionary-based theories.
- There is the recommendation to use multiple sources of evidence (triangulation, even multiple investigators). What we did through experts' comments and triangulation using the comments on each company by managers from others.
- There is the need to maintain a chain of evidence.
- There is, last but not least, the necessary creation of a case study data base (notes, incl. exact phrases (quotable phrases), documents…).

Besides, a series of other considerations led us in the framing and analysis of the case study.

First, we were looking at it as an exploratory case study. For, among the different purposes of case studies as a methodological process, the aim in our work was to develop pertinent hypotheses and propositions for further inquiry, to find relevant issues.

So the analysis of the case would involve:

- Ground analysis in theoretical propositions,

- Developments in case descriptions,

- Cross-comparisons (patterns, cross case syntheses),

- And generalizations (explanation building).

One key-thinking was also about rival explanations.

That is why we have structured multiple embedded case designs. The research topic was indeed not restricted to one sole set of companies in Europe.

And a comparison was enhanced with one other European cluster, plus the gathering of information on the development of the technology in the U.S.

This was enabling us to see potential variations within cases.

We also subscribe to the idea that Research is an iterative process.

2.1.5.9 *Research as an iterative process*

This process can be described as follow:

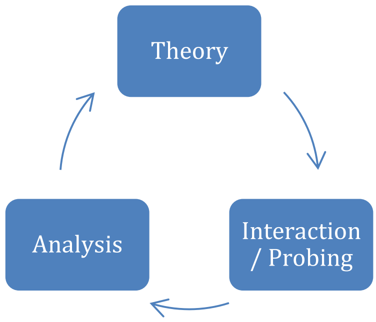


Fig. 32. Iterative process for theory enhancement

From an original set of concepts, the 3 steps are leading to enhance the theory.

These stages are clearly referring to lean management, quality insurance methodology and Deming's process.

The case study protocol presented below was serving this methodology.

Warning: A regular pitfall to be avoided relates to considering case-studies as a mere variant of other research designs as experiments.

But it is not valid, as is not valid the identification of case-studies to "one-group post-test-only design" (Cook & Campbell, 1979, p. 96).

In this case of micro-fluidics, then, the evidence is coming from 7 main data sources gathering in the 2 case studies.

These 7 main sources bringing richness to the cases are namely (in accordance with Fig. 31):

1- Public documents
2- Archival records / internal reports of the companies surveyed.
3- Direct observation of the clusters (at least once a week during 3 years).
4- Participant-observation through collaborative work with one among the spinoffs.
5- Academic articles based on the same case.
6- Previous knowledge.
7- And interviews with key informants.

The present work is mostly descriptive (not analytical) in its first chapters. And analysis will follow in further parts of the dissertation. Even if some comments on the reality described are giving way to explanations to come.

As such, the case studies presented are well in-line with an "analytic generalization" 'as opposed to a "statistical generalization".

2.1.5.10 *An Exploratory Design:*

One point is that the scope of study was eventually clear: The Performance of Spinoffs in two different technological clusters based on the same (Micro-fluidics) technology.

But, at the same time, there was no accurate proposition to validate preliminary to the study. That is why: the topic itself is the subject of exploration.

And this is the very condition to put in place a case study approach.

Beyond, and even if a lot of material is existing on both spinoffs' performance, and on clusters' emergence in industrial districts; managers of startups are still looking for additional methods and tools enabling them to predict the growth potential of their venture.

So, an in-depth inquiry of the conditions for growth in the framework of industrial emergence could lead to question the official history of micro-fluidics development in a somewhat 30 years period, ranging from the late 1970ies to 2012.

On the bases of the 2 identified clusters, we were likely to check if some misunderstandings at technological level are not leading to inaccurate or false conclusions about companies' performance in such clusters.
The existing articles and documents describing the English cluster seem to present some confusion as far as the technology is concerned. And peculiarly by confusing the positioning and evolution of the 2 main technologies, namely: CIJ and DOD.
That is why we have considered to re-writing the case on the English cluster. Primarily to confront the 2 standpoints.

And then in order to re-write, as and if needed, the story of the cluster.

Besides, we had in mind to give in this (potential) new version a renewed importance to the Technologies / Applications relationships.

2.1.5.11 *A « Two-case » design*

This design is said to be « a worthy objective compared to doing a single-case study" (Yin, 1994, p. 19).

But in the context of this work, another element is playing in favor of such a design: Indeed, if a microfluidics cluster started in England in the 1980ies, another cluster in France started around the same technologies and at about the same moment (1982 vs 1978). It is thus an easy way to "triangulate" not only some data, but beyond data: complete analysis about our findings on spinoffs performance based on the English cluster setting of evidence.

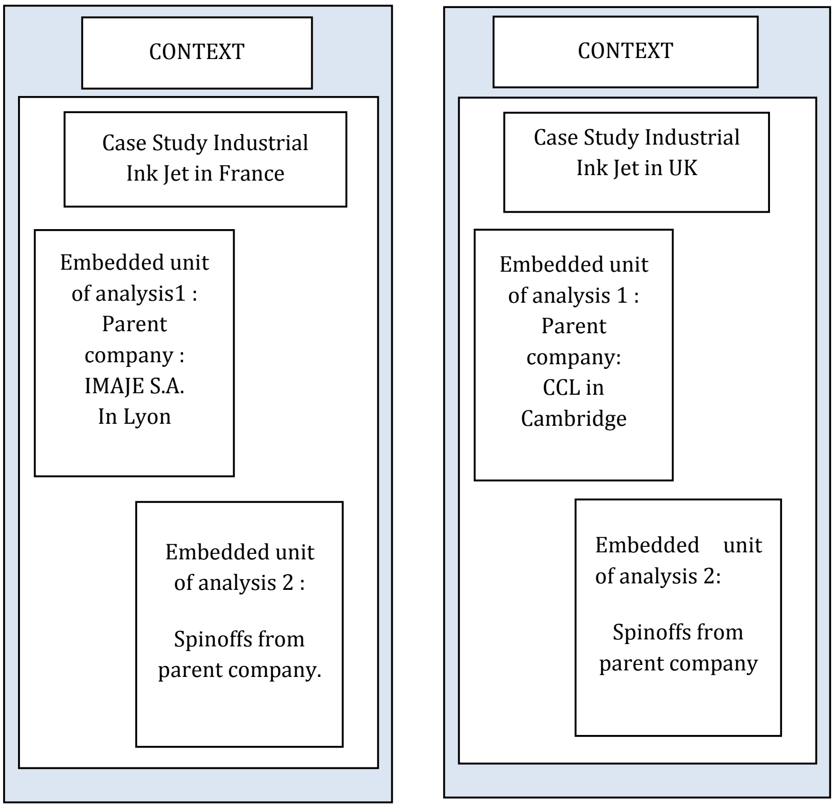


Fig. 33 Type of design for the industrial ink jet case studies: 2 case studies.

2.1.6 Cluster's sampling and Research Process

If the present survey is centered on the 2 European ink jet clusters, we are aware of the various initiatives that have been arising on the basis of this technology all over the world for almost 50 years.

We know that Japan had been quite active, even if not a precursor in this field.

And we have related in above parts of this dissertation the role played by Canon, Epson and other Panasonic in the development of the microfluidics sector.

We also know the importance of the US in ink jet history from the very beginning.

But as far as CIJ is concerned, it seems that no firm in the US nor Japan led to a kind of specific cluster.

2.1.6.1 *Ink jet clusters: U.S. vs Europe*

Many initiatives in the US led to the creation of ink jet companies all over the country, such as:

- Videojet, near Chicago, as the first player and leader in the ink jet coding sector.

- Marsh and Diagraph both in St Louis for DOD big characters printing.

- Cristo jet that grew with the help of the Lockheed company on the basis of a group having worked on their own ink jet solution.

- Branches of Kodak: In Dayton (Ohio) for continuous ink jet and in Rochester for the TIJ.

- Spectra that started in Darmouth (Ivy league's University), in New Hampshire.

- And not to mention the juggernaut H.P. in California.

That is why we show case the US cluster in the scheme below (Fig. 34).

But these initiatives were scattered in terms of geography, in terms of technology, and in terms of relationships.

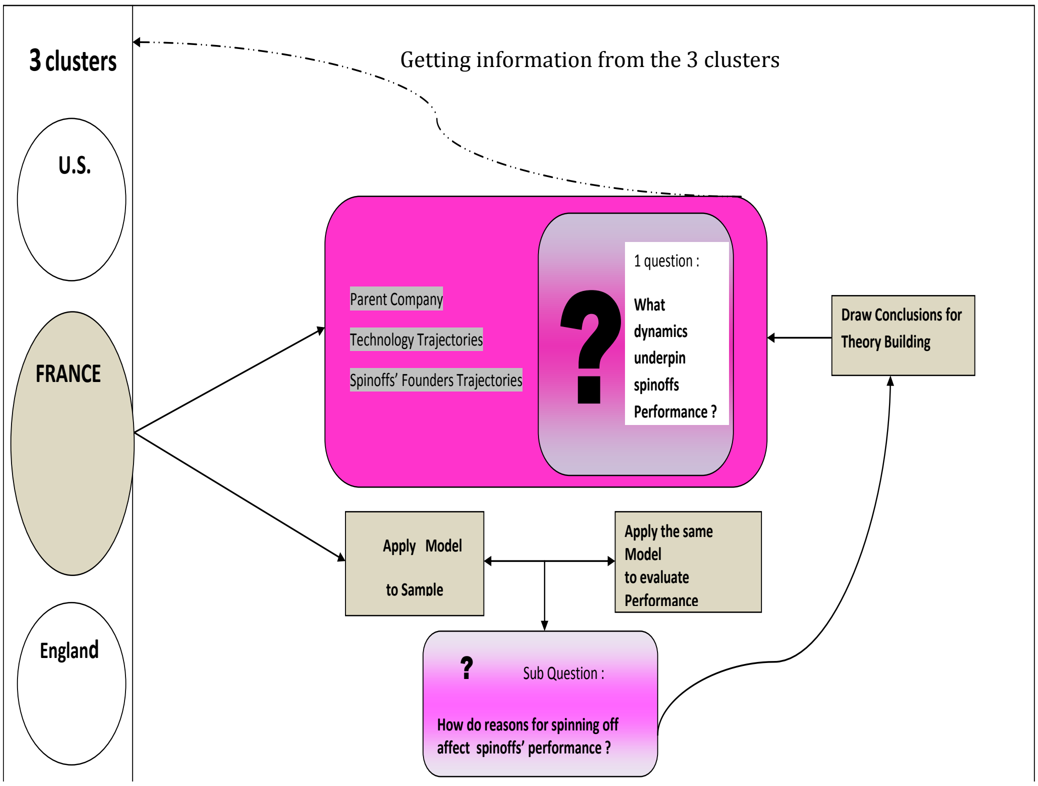


Fig. 34 Micro-Fluidics (1982-2012): Research scheme at origin

And, going back to CIJ to compare with what happened in Europe, it seems that no cluster did arise around the historical leader, Videojet.

Why?

When this flagship company of CIJ technology in the US started in the sixties, it inherited a technical design that was already well-established and reliable.

So Videojet initiated very few efforts to make the technology evolve. The dominant interest was attached to more geographical coverage and was not directed towards technical creativity and entrepreneurship.
That is mostly the reason why no company around Videojet is broadly known as one of its potential spinoffs.
Again, if we look in details, we can see probes of this rather conservative mindset attached to exploit rather than to explore new technological borders:

Thus, let us take *the piezo,* a key-component in an ink jet head, the head being itself the part where the technology gathers in a printer.
So, the piezo: This strategic part is by Videojet "almost the same than at origin" (A. Dunand)!

To be utmost accurate, it was slightly modified after the arrival of a new head (H. Pullen from Domino) for Videojet's technical department and its trials to make things change....

But there is no comparison to what happened at this level among the other ink jet companies (in Europe).

To the point that the very recent inventions implemented on Videojet printers are directly linked to patents coming from another company (Linx).

That is a clear proof of a certain lack of internal creativity; first of all if we compare with the so many technological changes initiated in the English cluster by the various spinoffs from the same parent.
It is true that this parent (CCL), as a technical consulting agency had the culture of exploration and dissemination of projects (specifically through spinoffs).

2.1.6.2 *The 2 European clusters*

- Chronological framework

In the late seventies, Thomson group was working in parallel on 2 projects to develop a Fax Machine.

This development was initiated by the main customer of Thomson for its mail activity: the French postal administration that had a monopoly at the time for this kind of communications.

2 projects were competing within Thomson group in terms of technology:

a- One based on thermal transfer printing technics.

b- The other one using ink jet technology and supported by Thomson HBS, a Thomson group's subsidiary based in Valence (France).

In those days, the two technics were at a very early stage of development and very few experts were to be found.

That is why the bulk of the ink jet project development was subcontracted to a scientific consulting agency based in England: CCL. CCL is standing for Cambridge Consultants Limited.

CCL had indeed previously acquired a significant knowledge in ink jet through a project, the very first one at the time, for this new technology in Europe: the ICI project.

It is to be noticed that several future key-figures of ink jet technology were part of the C.C.L. team: Ellen Pullen, Mike Kealing (who latterly founded the company Linx), some Xaar's leaders and others like Graeme Minto. Graeme Minto was then Fax project manager by CCL.

Thomson had ultimately chosen the thermal printing solution. Luc Regnault (co-founder of Imaje) was working on that project!

As a consequence of the choice in favor of Thermal Printing, the Ink Jet project was thus stopped by HBS.

Unsatisfied by the decision at group level to stop the ink jet project, part of the ink jet team within HBS, joined by Luc Regnault decided to launch a spinoff.
For the results of a market survey (under the patronage of HBS) on the potential of ink jet technology if applied to coding applications had showed very promising prospects.
Thus, in 1981, people still employed by HBS, are preparing the spinout.

The new structure was officially incorporated in 1982.
The general manager of the new company J.C. Millet first started as a distributor for Domino (U.K.)!
And Imaje took part to its very first fair by exhibiting Domino's printers!
This regularly hidden face of ink jet history proves nevertheless the early bonds that existed between the 2 European clusters. Even if this distribution scheme swiftly ceased.

We can then conclude on the initial statement about the history of ink jet in Europe:

Initial statement on the 2 European clusters	New version of history (PhD finding)
They are independent	***They were connected from the very early stage***

Table 2 - A new vision of CIJ evolution.

- Case study protocol

In the case of the Cambridgeshire Cluster, we have considered all the companies selected by Ford (see bibliography and below) in its various surveys.
In addition, and as far as information on non-quoted UK companies is concerned we used the FAME database from Bureau Van Dijk.
It was not enough, for this only contains a 10 year history!
We know that the database: Perfect Information Filings includes a module on Private UK companies, however we did not find any subscription to that particular module so we are not sure the length of history that is available through that source.
But we were able to get a longer history by applying directly to Companies House (http://www.companieshouse.gov.uk//index.shtml).

In the case of the French cluster, **no previous data was available**.
We had then to build the entire panel by ourselves.
Thus, between June 2011 and October 2012, more than 20 spinoffs from the same parent were identified and then contacted using available previous knowledge of the micro-fluidics sector and snowball sampling.

As an early stage of the survey: Most of the companies were identified

2.2 Methodology: Sampling & Analysis

The survey process was based on 7 different steps.

2.2.1 Step 1: Early stage

2 experts were initially contacted to identify the companies belonging to the French cluster. The purpose was to list the various companies that had spin off from the mother in this cluster. On the basis of a Delphi methodology, OB and AD (see table 5) were interviewed as experts and that brought to an extensive list of companies.

Names of SPINOFFS from IMAJE S.A. in the French ink jet cluster (20 companies identified).

Company	Location
APS	Valence (France)
Jason	Valence (France)
Ardeje	Valence (France)
Adaje	Valence (France)
Timis	Valence (France)
Marquage Product	Valence (France)
Codeco	Valence (France)
AOMS	Not based near Valence
Osmooze	Valence (France)
Dracula Tech.	Valence (France)
Ciamtech (Tiflex)	Valence (France)
Teampack (APS)	Valence (France)
Amici	Valence (France)
Impuls	Valence (France)
Ethersial	Valence (France)
Emblème	Valence (France)
Impika	Not based near Valence (Aubagne)
Siliflow	Valence (France)
Codesys	Valence (France)
Sepia	Valence (France)

Table 3 - Companies in the French inkjet cluster

2.2.2 Step 2: Selection

According to the purpose of the present research, among the initial 20 or so spinoffs identified, only 7 companies (Imaje included) were selected for the final sample.

The selection was conducted as follows:

- Among the 20 companies enlisted, we have first cancelled:
    a. The ones being mere sub-contractors for the mother company or other corporations.
    b. The ones that combined :

  -No employee instead of an activity for several years in ink jet

  -No innovative project

  -No manufacturing

- In a second step, we evacuated from the panel the companies that were no more independent at the moment of the survey (e.g. Teampack).

  All the above leaded to consider a series of 12 companies (group 1).

- Among these 12 spinoffs, 10 were considered as priority (group 2). And 5 of them as highly priority (group 3).

Group 1	Group 2	Group 3
Jason	**Jason**	**Jason**
Adaje	**Adaje**	**Adaje**
Ardeje	**Ardeje**	**Ardeje**
APS	**APS**	**APS**
Osmooze	**Osmooze**	**Osmooze**
Imaje	**Amici**	
Ethersial	**Siliflow**	
Amici	**Impika**	
Siliflow	**Timis**	
Impika	**Impuls**	
Timis		
Impuls		

Table 4 - Selection of Companies

The criteria to associate a priority level to the various companies in the cluster were:

The level of performance (a): Yes or no has the company developed in terms of Turnover and Number of Employees in its first 5 years after creation?

The level of disruption (b): Yes or no is the company targeting to develop an innovative branch in the Technologies / Applications tree of micro-fluidics?

The geographical vicinity to the Rhone-Alps Cluster (c): Criterion easily defined by itself.

The companies matching best these different criteria are the companies chosen in the sample (in addition to the parent corp. Imaje), namely: APS, Adaje, Ardeje, Jason, Osmooze.

We added in the sample (final sample) one company having a disruptive project but no significant level of performance. It was just to counter-check ultimately our findings.

This company is Ethersial.

That leaded to a target sample of 7 companies (mother/anchor company included).

For the other companies in the original priority group (10 companies), the decision not to keep them in the sample relates to:
Impika: Based in the south of France far from the cluster, even if linked in a way to it, historically.

Siliflow: Redundant with Ethersial (no performance).

Amici and Timis: No disruption and no project of disruption.

Impuls: successful company but no disruption, pure trader and at the limit of micro-fluidics.

According to the taxonomy splitting the sample, a specific strategy of research was applied to each group.

In a nutshell, using our general available knowledge of this industrial field, we have first selected a series of people involved in the micro-fluidics cluster for a long time.
These people have helped to make the list of the 20 companies or so having spun off from the same anchor: Imaje S.A. corp.

The spinoff process is covering the period 1982 – 2012.

It happened that this list is probably exhaustive.

All the companies listed where considered as active in micro-fluidics.

And we did consider only companies existing in 2012.

We had 3 reasons not to select companies having failed very fast at any past moment of clusters' history:

They were certainly under average performance when we were focusing on the explanation of outstanding performance.

Not only the data were scattered, but most of the founders were no more in the vicinity of the cluster.

There was no real reason not to have comparable companies at the specific moment of our survey (e.g. Ethersial). Just like at any moment in the cluster's life.

2.2.3 Step 3: Final setting of the sample

Then, the research process goes forward along the 5 different steps mentioned above: It **enabled to survey in details 7 companies** among the 21 (parent included) originally sampled.

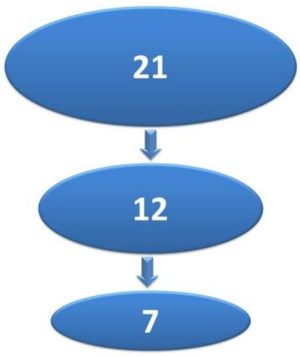


Fig. 35 Number of Companies in the sample

2.2.4 Step 4: Interviews

The scale of importance previously defined led to various types of interviews. 3 kinds of Interviews.

For each of the 12 spinoffs considered at origin (Group 1), the managing director and / or founder was contacted for the appropriate interview.
All the potential interviewees agreed to be interviewed. They are listed with their detailed position together with reference to the organization they are managing in APPENDIX 1 - Companies in the panels and interviewees.

Hereafter we give more details about the inquiry conducted, relatively to each group:

Group 1: The relatively low priority level of this group for the survey led to short encounters with the founders / managers and to the collection of general data on these companies as a first row.

Group 2: In-depth open-end interviews were conducted in a second row with the founders/managers of the priority companies. And accurate data on their 5 first years of existence in terms of revenue, turnover and payroll collected.

Group 3: In addition, for highly priority companies, several meetings were organized individually with the founders/managers and other actors on the specific topics of: Performance, Business Model and Disruption.

All the recorded interviews were exhaustively transcribed shaping a valuable database for further inquiry, after:

- Construction of the interview protocol to apply to the short list (cf. appendix)
- Iterative Test of the protocol on 3 companies and enhancement of the modifications (Ardeje / Ethersial / Jason).
  The test was completed by an evolution of the method of data collection itself: from this moment on, each and every interview was recorded and a picture of the respondent shot and filed systematically.
- Completion of the data collection.

  The data collection was conducted on the basis of semi-directive interviews. Their duration was approximately 2 hours each. Meetings were previously scheduled with the founders of each company in the sample, once the person identified.

2.2.5 Step 5: Qualitative Analyzis

The results were gathered, organized and analyzed.

And findings led to write a new version of history of industrial inkjet development.

This new version was submitted to comments from experts.

2.2.6 Step 6: Experts' comments

3 experts (see Table 5) were involved in the research process to validate internally (intrinsically) the findings.

These experts have a broad as well as in-depth knowledge of the micro-fluidics technology.

Each of them has more than 20 years of experience in ink jet.

And they all know a complete version of industrial ink jet technology's history.

Experts' names	**# years of experience in micro-fluidics**	**Position**	**Chief Concern Science vs Markets**
Olivier BASTIEN	20 years	General manager of inkjet companies in various contexts	Markets
Alain DUNAND	30 years	Scientific Head in micro-fluidics Dover Group	Science and Markets
Arthur SOUCEMARIANADIN	30 years	Dean of INPG micro-fluidics	Science

Table 5 - Inkjet Experts interviewed.

These experts, all well aware of the evolution of the French cluster in Valence, were chosen among 7 potential experts initially identified.

They were more intimately matching the needs of this research because they were in part complementary and in part redundant.

They were complementary for their main exposure to science or market was diverse.

They were redundant because 100 % of their long professional experience was coming from micro-fluidics.

The will to have comments and feed-back from several experts was attached to the importance of using multiple source of evidence from multiple experts.

Such a research process enables cross-comparisons on patterns, visions and facts.

This method is also leading to the triangulation of some pieces of information peculiarly sensitive and conclusive.

2.2.7 Step 7: A new version of history.

The comments of the experts are then confronted and combined on the basis of a Delphi approach. General conclusions are eventually drawn.

All along the research process, and in addition to findings at company level, the French industrial inkjet cluster is described and analyzed in the framework of a case-study. This qualitative analysis of spinoffs from the same parent brought to conclusions on the mother company / spinoffs relationships. This also revealed the existing connections between the 2 European clusters from the very beginning of ink jet technology successful course.

The writing of the case-study about the French cluster was thus leading to review also the pre-existing accounts on the cluster in England.

As a consequence, a new version of the whole history of industrial inkjet was to be delivered.

As far as the methodology used to work on the 2 clusters is concerned, we knew that two specific points deserved to be specified.

For they had a specific importance in the context of our specific survey:

That relates to the importance given to the triangulation of sources on one hand; and on the idea to consider not one but two case studies on the other.

As a consequence, a new version of the whole history of industrial inkjet was to be delivered.

a- Various standpoints:

The importance given to the triangulation of sources served our wish to have a rich and renewed vision of the history of ink jet. The official version of the cluster's development was thus completed by multiple complementary elements. None of the interviewees had a full version in mind with all the details. But each was able to contribute with specific comments. So we discovered for example that most of the spinouts invested in technologies that were not targeted by the mother company in the French cluster (piezo DOD with UV inks, thermal ink jet, mono canon heads …). In such a case, instead, the parent was considering the child as a mere copy of what previously existed in the mother company.

The startups' founders were just arguing about the reverse: A new venture with an original technology to develop and promote!

A third party (triangulation) was then essential to conclude.

b- 2 case studies: Why?

The purpose of considering 2 case studies was at first attached to the idea of comparing 2 clusters, 2 independent stories, in different countries with different players to ultimately check findings. But in the end, a "serendipitous" process led not only to compare 2 stories, but also to complement the research on the French cluster by analyzes conducted on the English set of ink jet companies.

2.3 The 2 case studies on dynamics of Industrial true emergence

Contents:

- Context of the case studies.
- General analysis of the cases
- A new version of history.
- Tentative Conclusions.

2.3.1 Context of the case studies.

The present case-studies are focusing on the Ink Jet Printing (IJP) industry in the vicinity of Cambridge (UK), and Lyon (F) and explore the emergence and maturation of knowledge-based clusters of activity.

The lineage of firms in these local clusters is examined with reference to their technologies, their founders and their spinoff activity.

Evolutionary issues are addressed tending to understand what and how dynamics operate.

Even if the main purpose of this dissertation is not to understand why, in fact, do employees of high-tech firms leave to found new venture.

Among the numerous empirical studies that have mushroomed to explain spinoffs, some are highlighting the heritage of spinoffs, suggesting parental involvement from the mother company. This relates to the so-called "planned spinoffs" (Dyck, 1997), by opposition to unplanned ones.

In this prospect, it is not surprising to find that new ventures develop in a business similar to their parent's.

More commonly, 3 main perspectives can be drawn to predict spinoffs creation:

- Agency theories: this first model features that the parent company doesn't want to invest more in the innovation project because of its cost structure (Wiggins, 1995), Anton and Yao (1995), Bankman and Gilson (1999).
- Organizational capability theories: This way to explain spinoff is focusing on organizational reasons leading the incumbent not to invest further in the innovation project (Tushman and Anderson, 1986; Christensen, 1993).
- Learning theories: In this case, the entrepreneur himself aims at avoiding the parent company to be associated with the innovation project on the long run (Franco and Filson, 2000).

But is there a linkage between these reasons leading to start a firm and the level of performance of the firm founded?

While studies of industrial emergence and reasons for spinoffs have been broadly documented, the implications for **predicting** spinoffs' performance remain underdeveloped.

Indeed, when so many articles and studies of entrepreneurship, high-tech and high-growth start-ups have crafted new theories to explain spinoffs, few surveys underline the bound between entrepreneurial motivation and spinoffs performance.

Shaped by previous work, a picture is nevertheless emerging about forces underpinning spinoffs' performance in relationship with the initial impetus for creating a new venture.

The purpose of this subsection is to bring this picture to focus.

It builds on previous theorizing on the topic of spinoffs' performance through the study of the 2 main inkjet clusters in Europe.

The various prior perspectives bearing on spinoffs in ink jet clusters suggest the importance of technological enhancements and of the skills previously acquired by their founders as far as the performance of the company surveyed is concerned (Kleper, 2001).

Beyond well-established performance criteria, the present study specifically intends: to reveal insights on ***the crucial role of capturing an outstanding high value per customer in the development and growth of spinoffs***.

Related questions: Why do customers accept to pay such a value? Why do they agree to pay a price representing sometimes a very high amount in terms of TCO (Total Cost of Ownership)?
How does a so-called "dominant design" manage to impose itself to various kinds of customers, and particularly to the ones not really aware of the costs associated to the technology promoted!? What about the trade-off between the potential of the technology and its cost-to-use?
Besides, we were interested to evaluate the value created by various solutions at different levels of the technology tree:

- By comparing ink jet versus laser. We thus compared the 2 main branches of printing technologies.

- And by comparing the technologies represented by the companies in the 2 ink jet clusters. We thus compared two sub-sections of ink jet technology.

- Issue 1: Why was inkjet so successful in comparison with laser?

The dominance of ink jet over laser historically is very clear: The two technologies emerged almost simultaneously (in the 1980ies).
But when we look at their respective development, one figure is enough to show the difference in terms of market potential:

Year	1990s
Laser Market share (worldwide)	**15%**
Ink jet Market share	**85%**

Table 6 - Market shares Inkjet vs Laser (Source: Clinvest Report)

The gap was never bridged by laser.

Was it a question of disruption?

In "pure" terms of technology, the 2 of them were equally disruptive compared to the traditional Gutemberg-style contact printing techniques (flexography for example).

So the difference between laser and ink jet in terms of success is not technology disruption-related.

Was it a question of nature in the disruption?

If we refer to the difference explained by authors between technology disruptions on one hand and business model disruptions on another hand, some reasons for the gap could come from this side.

We develop this topic further in the dissertation (see the part Disruption theory and outliers).

But we can without delay consider that the business model of companies promoting the laser technology is nearer to the business model of flexography than to the one of ink jet. At least, as it is shown by the revenues coming from the installed base.

Criteria (inspired from a Kano model type)	**Laser CO^2**	**Ink jet (CIJ)**
Output	Up to 80 000 marks per hour	Up to 100 000 prints per hour
Capital equipment cost Installation included	33-35 K€	11 – 12 K€
Consumables, parts and service **Yearly Cost per Printer**	Very low running costs (no inks) 0.7 K€ (≈ 2%)	Yearly maintenance and fluids > 20 % of the capital investment 2,4 K€
Constraints ….	High capital cost (3 x ink jet) Lower speed Permanent mark Head has to be close to cabinet Limited range of substrates Bulky and inflexible cabinet (less) Versatility (if not Beam technology)	- No permanent mark - Ecological concerns

Table 7 - Cost comparison Inkjet vs Laser (Source: CLinvest Report p.26)

In flexography, we consider the following data:

Pad printer price	1 5000 € (for 2 colours)
Price of the tooling	< 100 € (printing plate)
Weekly prints per production line	25 000 marks with 5 characters
Shifts per day	1 shift / 8 hours
Price of a pad	20 € (for 200 000 prints)

Table 8 - Flexography printing references

Then, we can evaluate the ratio consumables / equipment for flexography in addition to the previous table (see also appendix

We obtain:

Yearly revenue for 1 200 000 prints per year: 20 x 6 = 120 euros.

These calculations are based on Pad Printing Costs estimations by John Kaverman (Innovative Marking Systems, 2004).

Now, if we compare the yearly revenue (120 €) to the capital equipment cots (1600 €), we get 7.5 %.

This figure is slightly higher than the corresponding percentage for laser (<5%), but in the same range, and with a very weak absolute revenue!

So, as for laser, flexography is well far from the razor/blade or the ink/ printer business models.

- Issue 2: Do we have strong differences in the evolution of ink jet companies themselves according to the sub-technology chosen?

To detail this issue we will compare the level of growth in revenue terms ***for 1 printer by 1 customer on a yearly basis*** for the various solutions (sub-technologies*) represented by the companies in the 2 clusters.

* Piezo inkjet

Cumulative yearly revenue per cust. / **Techno / Companies**	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
DOD piezo (Inca / GB – Ardeje F) Yearly revenue per customer/ cumulative	2,07	4,14	6,21	8,28	10,35
CIJ single nozzle (Domino,Willett, Lynx / GB – Imaje F) Yearly revenue per customer/ cumulative	2,4	4,8	7,2	9,6	12
CIJ multiple nozzles (Elmjet /GB) Yearly revenue per customer/ cumulative / Turnover and payroll evolutions	6,55	13,1	19,6	26,2	28,8

Table 9 - CIJ Technologies: Cost comparison over 5 years.

Why do we have so strong differences?

The benchmark above, and the analyses to come in accordance, will clearly state the contribution of the Thesis in a kind of re-writing of the history of the technology as we mentioned it already.

Indeed the findings of the work are giving a different light than the usual theoretical criteria linked to performance, namely:

- Comparative advantage (Porter, 1986)
- Position in the value chain (Porter, 1986)
- Reasons to create a spinoff (Klepper, 2001)
- Initial conditions impacting upon the trajectory followed (Nelson and Winter 1975; Malerba, 2007).
- Interaction or coupling between supply and demand considered as particularly important by Swann (1994), Arthur (2007), and Nemet, (2009).
- Catalytic events that can significantly enhance the rate at which emergence occurs (Hourd and Williams, 2008).

- Fractal nature of industrial emergence. That is, there are several levels at which emergence can be observed and cycles occur: industry-level, market-level, firm-level, product-level (Nelson and Winter, 1975; Ansoff, 1984; Murmann and Frenken, 2006).
- Entrepreneurial agency through the experience of the new venture's first members and the balance between technical and commercial expertise at origin (Ford and al. 2011).

One additional criterion: the RECCURRENCE of the value (once captured) put a new perspective on the above whole traditional set of performance's criteria.
Understanding this criterion as operational enables its direct use by managers and leaders in their strategies. By being operational, this piece of criteria is bearing an epistemological value.

Indeed, it brings to light the epistemological value of singularity: When most managerial theories – Porterian ones or others from the same kind– always tend to explain the world as a whole, our approach is aiming at giving a new sense to some individual cases.

Not by considering any individual case as a mere element in a general law. But by considering what it can bear as very specific and interesting accordingly.

In the same way that one can study a specific genetic code belonging to only one individual on earth, without looking for general conclusions on the human species.

The goal being to try to understand the singularity to be able to RE-BUILD or duplicate the case, if expected.

To support this reasoning we are using the concept of outliers promoted by Malcolm Gladwell (Outliers: the Story of Success, 2008), and easy to apply to outstandingly performing companies.

In fact, applied to management and inquiries, this approach intends to reinforce the operational side of the research. It is no more a question of bell curves defining ex-ante rather abstract and more or less realistic situations.

The purpose is to escape from average or majoritarian single considerations and exclusive deductive logical processes.

The idea is mostly to envision, from one previously well-defined piece of reality, new consequences (applications fields?) from the results of in-depth surveys.

Indeed, some characteristics, without being generalizable, can be researched in other categories. These taxonomies can refer to companies or sectors of activities and be applied by induction to the new environments defined.

In this sense, the research in management, and, as a part of it, in management of technology, is offering sets of advice for action to managers.

This operational side of research work is directly related to an **applied science.**

The fact is not that current theories in management would be methodless.

But it is easy to state that the managerial tools coming from management theories are short in their application of in-depth knowledge; in the sense of an in-depth understanding of the situations to be considered.

Particularities are most of the time neglected in favor of sets of generalities.

Again, it is not that the art of management is lacking of methods. But the managerial application of the methods, because of lack of time and means of investigation, can be too superficial. And it does not sufficiently take into account the psychological side of a given company (dynamics of actors) or the research of specific data… This, when a key motto of strategy is to differentiate from others!

In fact, by adopting a « bottom-up » approach and starting from concrete ("from the field") and specific criteria (specific to the situation) one can target highly operational parameters.

This kind of criteria is not only trivializing the other sets of criteria, but also makes very relative the interest of a systematic and broad conceptualization of systems in terms of (e.g.): Competitive advantage, disruptive innovation, competitive forces or offer/demand interaction.

As a consequence: If we consider a high-tech sector as inkjet, by elaborating on table 9, we could imagine that when **the RECURRENCE in the business appears to be exceptionally profitable**, then all the other strategic analysis criteria could be secondary!
And, as a consequence, the outstanding profitability when dealing with a customer becomes a key as a performance factor.

Thus, a real manager can make financial errors, the competitive advantage regarding the other actors can be insignificant, and the quality can be under expectation …. In the case of an exceptionally profitable recurrence, the performance could nevertheless be there. At least for a while …

The performance manifests either directly through the development / sustainability of a defined spinoff, either indirectly through take overs, mergers … enabling to optimize the management of the company.

The case of inkjet clusters could be, in this way, extended to cases like Microsoft or Google; or even to less technological ones like Nespresso.

And if the last part of the dissertation aims at giving rules to apply, we underline, all along this work, the importance of inductive qualitative methods (like the bottom-up prospective) to give in-depth understandings of spinoffs' performance, specifically.

But it is not in any case a way to condemn quantitative, deductive, top-down methodologies.

Indeed, we do consider and subscribe to the general idea that these both bodies of tools and methods are not exclusive from each other.

Nevertheless, the single usage of quantitative models and tools can affect in a negative way the findings in numerous researches.

In the case of inkjet clusters, we are in a position to state that the surveys on the dynamics of start-ups and spinoffs, and more generally the history of this technology, are regularly biased.

When referring to some articles about the European ink jet clusters, several inappropriate comments can systematically be listed:

- Statement 1: About the maturity of CIJ vs DoD technology: "CIJ is currently at a mature stage (…) DoD technologies have yet to mature". (*In Insights from industrial ink jet printing, Ford et al. 2011, p.2.)*

- Statement 2: About the difficulties for DoD technology to penetrate the coding market: "When DoD was first commercialized [in 1990] it was anticipated that it would also be used for the coding and marking of packaging. However DoD print speed at this point was insufficient for most applications and it only managed to penetrate 5% of this market". *(In Insights from industrial ink jet printing, Ford et al. 2011, p.6).*

- Statement 3: About disruption: "in the late 1980s and early 1990s ink jet printing disrupted dot matrix printing, then the dominant design in desktop printing " (*In The emergence and Development of the Cambridge Ink Jet Printing Industry, Garnsey et al., 2009, p.8).*

- Statement 4: About product identification as a niche market: "Incumbent firms were stretched by the home and office printer markets and left a product identification market to new entrants". (*In The emergence and Development of the Cambridge Ink Jet Printing Industry, Garnsey et al., 2009, p.10).*

All these assertions need to be restated to become consistent with the whole complexity and the reality of ink jet history.

Comments on *Statement 1*: CIJ could be considered at a mature stage as far as the SCP branch of CIJ was concerned. But Binary Jet, another CIJ technology, is still struggling for some significant development.

Comments on *Statement 2*: Years before 1990, companies like Marsh, Markpoint or Swedot were already manufacturing and distributing DOD products for the coding and marking of secondary packaging!

This DOD technology branch called "LCP" (Large Character Printing) was no less than dominant for on line printing on corrugated boxes and cartons!

Comments on *Statement 3*: The statement is true but covers the single desktop printing applications and for DOD piezo only!

Comments on *Statement 4*: incumbents in the home and office markets could NOT dominate the product identification market!
For the 2 technologies - even if both referring to piezo systems - are not substitutable with one another!
The technical basis is absolutely not the same. As shown previously, DOD piezo and SCP piezo are historically targeting very different applications.
The targeted substrates were ***exclusively porous*** ones for DOD piezo (hence the SOHO markets). When the targeted substrates were mostly non-porous for SCP piezo technology (plastics, metal, glass…).
Not to mention de difference in speed enabling SCP to reach 5 meters/second and more, when DOD piezo with aqueous inks had difficulties to run 1 meter/second.

An insufficiently in-depth understanding of the micro-fluidics technology constraints and lineage (between the various technical enhancements) is leading to approximate conclusions on the technology evolution. It is also leading to approximate conclusions on the levers for growth and development of high tech spinoffs.
We could sum it up the following way: How bad technology understanding is leading to false conclusions on performance analysis?

Performance, as used in this paper, is referring to "the multidimensional nature of performance" as stated by Woo and Willard (1983).
The idea is to consider, even if unusual, a large number of performance variables.

For, as Barney (1997) analyzes it, the use of one sole criterion is not enough to measure firm performance.

So we mostly consider the Taxonomy of Cooper, Gimeno-Gascon and Woo (1991).

According to this model, the measure is traditionally based on 4 main performance metrics:

- Growth: Turnover and number of people.

- Absolute size of the company.

- Objective criteria: (financial ratios mainly).

- Subjective criteria.

We are also considering a second type of model, a second type of analysis. It involves monitoring the marketplace for niches that industry leaders might have missed. This type of strategic consideration, strategic behavior is labeled "applications engineering" by Ansoff and Stewart, and "opportunistic" by RE. Freeman.

In a nutshell, every time we consider a company in the clusters, we intend to evaluate its performance in terms of ***growth and objective criteria***.
And every time we consider a technology, we intend to evaluate its ***efficiency for dedicated applications.***

2.3.2 General analysis of the cases

Studies of true emergence of industrial clusters have tended to focus on the role of disruption in the performance of spinoffs, but few of them have underlined the intimate link between **technology choices** and the performance potential of a start-up.

A theme that we developed by observing the 2 European ink jet clusters like two combining case-studies.

For each case, we conducted a sequence as follows to state the cases and prepare the data analysis and conclusion.

1 - We first describe the 2 early linkages at clusters' origin.

2- We then describe in details the clusters:

- The various firms (spinoffs).
- The links between companies (shaping a network).
- The parent company.
- The evolutions of the linkage between companies (in time and space).

At last, we exploit the data for a conclusion; in a new chapter.

2.3.2.1 *Clusters' origin*

2.3.2.1.1 The Inkjet cluster in UK (Cambridge): CCL universe

2.3.2.1.1.1 General overlook of the ink jet cluster in U.K.

The following graph is showing the genealogy of the British European cluster seeded by CCL group at origin.

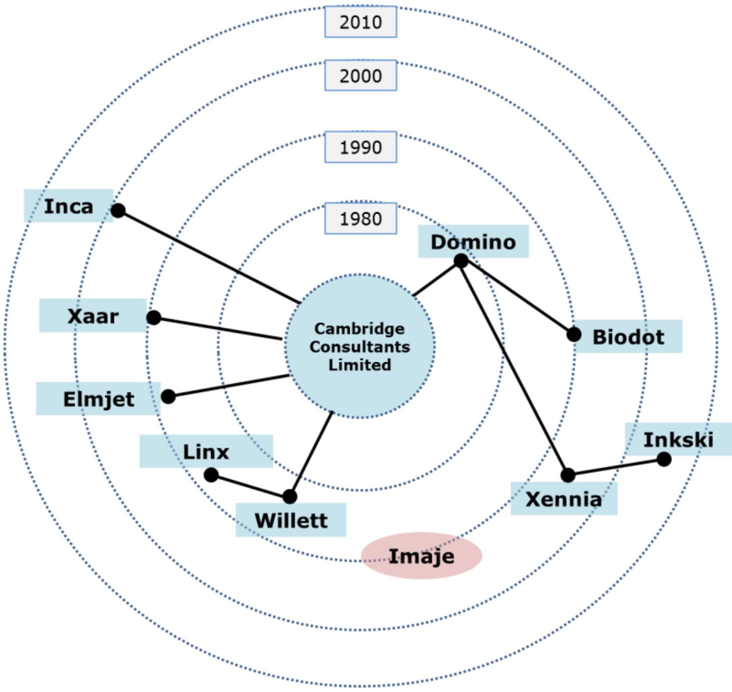


Fig. 36 Synthetic lineage of the U.K. ink jet cluster

2.3.2.1.1.2 CIJ in Cambridge

As mentioned before, early scientific breakthroughs in the area of continuous ink jet (CIJ) were made in the 1960s by Richard Sweet at the Standford Research Institute (SRI).

He was not involved in the commercialization of the science. Instead, one of the first firms to develop the technology was CCL (Cambridge Consultants Ltd), a technology consultancy company.

When people consider this origin of the inkjet cluster in U.K., they do not consider, or at least do not underline, the fact that this cluster is originally **embracing a small part of inkjet technology** (See Fig. 37). What we demonstrate here after.

Indeed, the inkjet printing industry is divided between 3 various application fields of the micro-fluidics technology:

- Industrial applications: they relate to products developed for marking, labelling and coding on production lines.
- Printing applications: they relate to commercial printing.
- Home and office equipment applications (SOHO/Small Office and Home printers): they relate to desktop printing.

This market is twofold: revenues are coming from the devices (the printers themselves), but also from the fluids. And the latter is not to be underestimated:

> In 2009, Pira international (a worldwide authority for the print industry) was thus sizing the industrial inkjet ink market (Soho excluded) at $33 billion turnover worldwide.
>
> Besides, Pira segments this market into several sectors, as shown in the figure below:

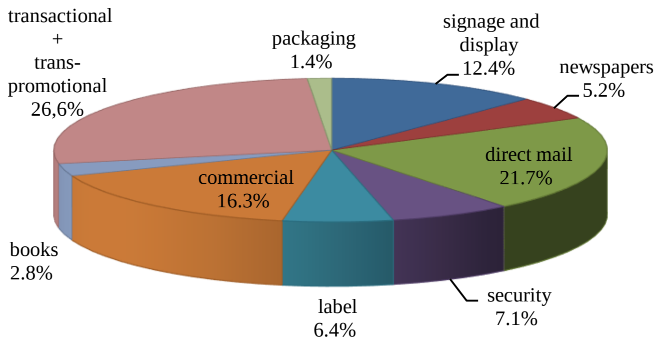


Fig. 37 Global inkjet print market sectors in 2009 by print volume (adapted from American Printer, 2006 and Inkjet Printing case report CBR J. Thomson, 2009).

Revenues from hardware, media and chemistry reached $59bn in 2009. *The largest segment of revenue came from ink*, contributing alone almost $33bn, more than 55% of total revenues (American Printer 2006). This is consistent with Pira data.

Although very complete, the figure above is nevertheless not reflecting the huge difficulties to cover the various market sectors with the same technology.

According to the 3 field of applications considered (industrial applications / printing applications / home and office), it has to be noticed that the 2 clusters surveyed were outstandingly successful, mainly for the packaging industry (industrial applications).

That is to say: for a segment covering no more than 1.4 % of the global inkjet market! (See Fig. 37 Global inkjet print market sectors in 2009 by print volume (adapted from American Printer, 2006 and Inkjet Printing case report CBR J. Thomson, 2009)..

Indeed, when CCL spun off from Cambridge University, at the start of the 1970s, this technical design consultancy was working on Continuous Ink jet (CIJ) technologies.

An inkjet technology mainly used to code best before dates on packaging.

At that time, though, CCL had primarily contracted with the chemical multinational group ICI to prototype an ink jet printer for printing onto textiles.

The goal was to print on textiles at very high speed, over wide width and in full colour.

ICI withdrew from the project a few years later when it became clear that the level of complexity required to achieve quality and cost targets was very significantly superior to what was expected at first.
When authors mention that it was "reflecting the nascent phase of the IJP technology at that time" (Garnsey, 2009 p.9), it is to be noted that the technology considered here (CIJ) would ***never*** after be efficiently in use for this kind of applications!

Indeed, the technology considered at that time could be in details characterized as: Single nozzle *CIJ* using solvent-based inks.
When today the inkjet technology used is almost exclusively *DOD (piezo)!* Moreover, the inks jetted are water-based.
So it is just the other master branch of the technology tree…
For this inkjet DOD technology is less "complex" (than the CIJ): no gutter, no deflection.... and with a better quality of the print.

Let us note that at the same time, in the mid-1970s, IBM released, using CIJ technology, the first peripheral, the IBM 4640 inkjet printer (1976).

Going back to Cambridge emerging cluster in these years, it happened that: In spite of the withdrawal of ICI, the project leader at CCL, Graeme Minto (cf. part 2.1.6.2) had clearly in mind the commercial potential of the technology. So, with the support from CCL, he spun out the technology in a new company founded in 1978: Domino Printing Sciences.
Domino was an independent startup which took over the intellectual property in the technology from ICI and CCL.

Further on, in the 1980s the cluster in UK was still dominated by both CCL and Domino, the 2 early actors making almost 100% of the IJP employment in the region (Cambridge University Engineering Department High-Tech database, 2009).
Then, the Cambridgeshire local IJP industry more than tripled from the late 1980s to the early 2000, then decreasing somewhat following 2000; before increasing again after that..
But if the early 2000s show CIJ entering a maturity phase, it was not the case for all the IJP technology branches, in opposition to what was mentioned (Clymer and Asaba, 2008) by several writers.

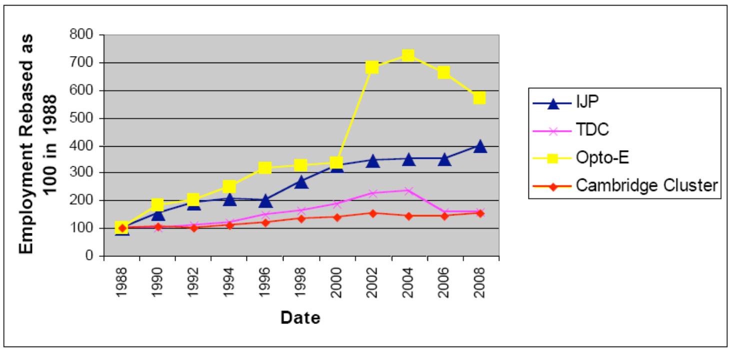


Fig. 38 Growth of the various sectors in the Cambridge cluster (source: Evans and Garnsey, 2009).

Indeed, and as shown hereunder, the growth for the main players in the desktop IJP industry still amounted to more than 12 % a year, in 2010.

Vendors	2010 Unit Shipments	2010 Market Share	2009 Unit Shipments	2009 Market Share	2010/2009 Growth
1. HP	52’740’770	42.1%	45’634’488	40.8%	15.6%
2. Canon	22’653’082	18.1%	21’077’887	18.9%	7.5%
3. Epson	18’269’836	14.6%	16’657’618	14.9%	9.7%
4. Samsung	6’891’155	5.5%	5’373’732	4.8%	28.2%
5. Brother	6’714’144	5.4%	6’366’899	5.7%	5.5%
Others	17’950’746	14.3%	16’621’517	14.9%	8.0%
Total	125’219’733	100.0%	111’732’141	100.0%	12.1%

Table 10 - Worldwide Desktop Printers’ Market Share and Year-Over-Year Growth, 2010

In fact, the emergence and development of the Cambridge IJP industry **should be seen mainly as the development and growth of CIJ technology in Europe.**
This growth having been stimulated by new standards at the turn of the 21st century in terms of European legislation related to consumer information on packaging, mostly in the agro-food sector.

This explains the sudden pick in development of companies like Domino, Linx, Imaje and Videojet between 1990 and 2000.
All these companies were specializing in CIJ for printing best before dates on packaging at the time.

Companies	**# of employees > 100 after 5 years**	**# of employees after 10 years > # of employees after 5 years**	**Technology**
Xennia	No	No	DOD
Imaje	No	**YES**	CIJ Single nozzle
Inca Digital	No	No	DOD
Biodot	No	No	DOD
Xaar	No	No	DOD
Elmjet	No	No	CIJ multi nozzle
Videojet	Yes	**YES**	CIJ Single nozzle
Linx	No	**YES**	CIJ Single nozzle
Domino	Yes	**YES**	CIJ Single nozzle

Table 11 - Employment in the Cambridgeshire Ink Jet Printing industry
(Adapted from: Cambridge University Engineering Department high-tech. database 2009).

As said in several articles on IJP industry (Garnsey, Thomas, Stam, 2009; Ford and al., 2011): The burst of the demand for IJP linked to new regulation standards stretched incumbent firms on the home and office printers wide market to new entrants.
But not, as presumed, in the opportunistic manner depicted by Penrose (1959) for new firms in emerging industries.
Because, and again for technological reasons, this sub-market of coding equipment in the wider IJP industry was essentially not accessible to incumbents in the SOHO.

Indeed, at least 3 sets of reasons make very rare the opportunity to use a kind of desktop printers for coding packaging on line in a production plant:

- Most of the substrates are not porous, rendering the efficiency of water-based inks mostly doubtful.

- The speed of a production line in a modern factory packaging food or beverages is regularly above 2m/s. And this speed is not compatible with the technologies used for desktop printers.

- Last but not least, the head/packaging distance makes the use of desktop technology on a line very problematic. Typically: A desktop printing head is “kissing” the substrate revealing a standard distance of something like 1mm when CIJ can be jetting at 10mm (or more) from the substrate. This later condition is matching more obviously the variation in size of the packaging themselves.

All this, without even mentioning the expectations in terms of robustness and reliability expected for an industrial product in a factory.

2.3.2.1.2 The ink jet cluster in France (Lyon): Thomson universe.

2.3.2.1.2.1 General overlook of the ink jet cluster in France

The following graph is showing the genealogy of the French European cluster seeded by Thomson group at origin.

Only the selected companies for the ultimate survey are mentioned, plus the 2 spinoffs from Ardeje to enable further comparisons with the UK cluster.

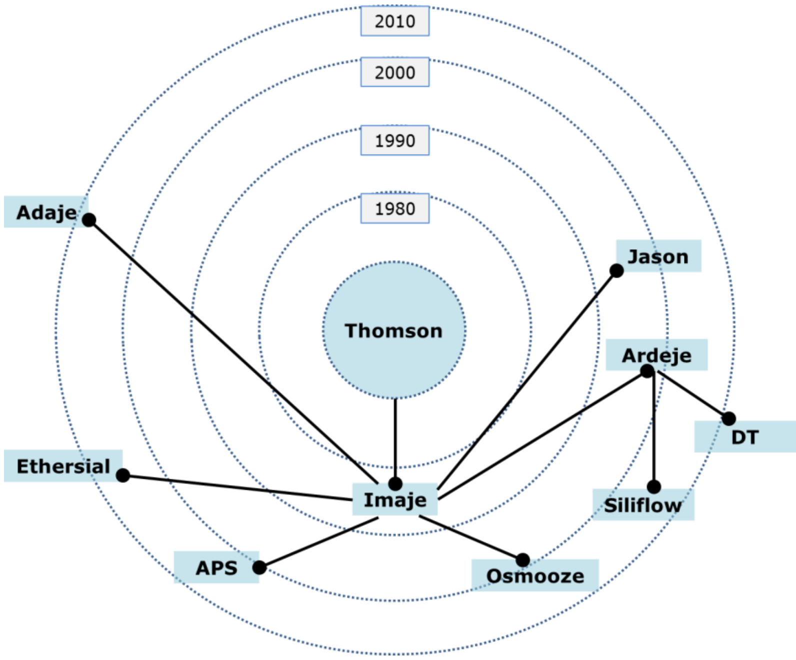


Fig. 39 Synthetic lineage of the French ink jet cluster

2.3.2.1.2.2 Performance

As shown in the graph above, the local inkjet cluster in France can be traced to one organization: IMAJE S.A.

As for DOMINO PRINTING Sc. in U.K., the performance of IMAJE was outstanding during the very 5 first years after the launching (see table below).

The performance measured in terms of growth in turnover and in headcount as well.

Year	**1982**	**1983**	**1984**	**1985**	**1986**	**1987 (e)**
Turnover (MFF)	**1**	**10**	**35**	**59**	**72**	**100**
Number of employees (end of date)	**8**	**32**	**60**	**100**	**160**	**200**
Installed base (number of heads SCP)	**4**	**100**	**450**	**1100**	**1720**	**3200**

Table 12 - IMAJE S.A. figures for The 5 (+1) first years after the launching.

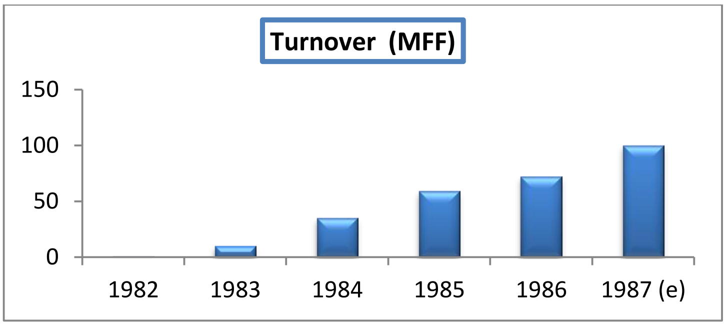


Fig. 40 IMAJE S.A. Turnover for the 6 first years after the launching.

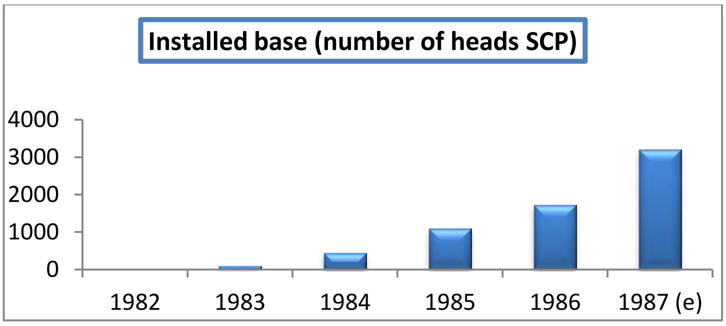


Fig. 41 IMAJE S.A. installed base evolution over the 6 first years after the launching.

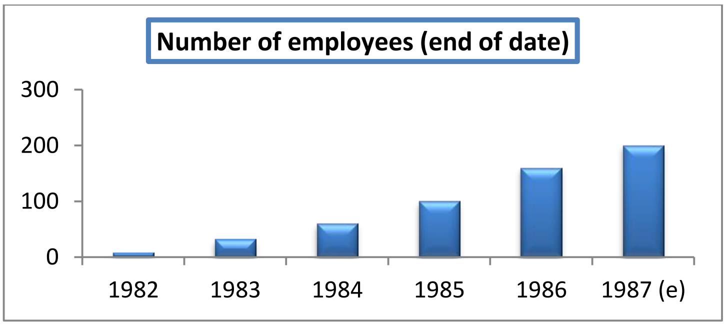


Fig. 42 IMAJE S.A. staff evolution over the 6 first years after the launching.

2.3.2.2 *Details of the clusters (Data)*

2.3.2.2.1 - A strong entrepreneurial dynamics:

The above facts and figures are showing a strong entrepreneurial dynamics in the 2 clusters.

That is true when considering:

- The number of companies created,
- The number of technologies developed,

- And figures on the generated jobs.

As the EEDA and the Cambridgeshire County Council mentioned it in their 2005 report about "the Birth of a World-Class Cluster" (the industrial ink jet cluster in Cambridge):

- The total current revenues overpassed £1 billion!
- The Total headcount (new jobs) amounted to more than 3,000,
- And the Ink Jet Cluster enabled not only new technologies but new complete fields of activity like those attached to the emerging "Plastronics'Cluster".

And diaspora from each of the 2 European ink jet clusters populated Ink Jet Industries in international locations. Even if new companies in England were more supported…

2.3.2.2.2 - New companies in England were more supported.

Indeed, a financial cluster followed the technology cluster in the case of Cambridge.

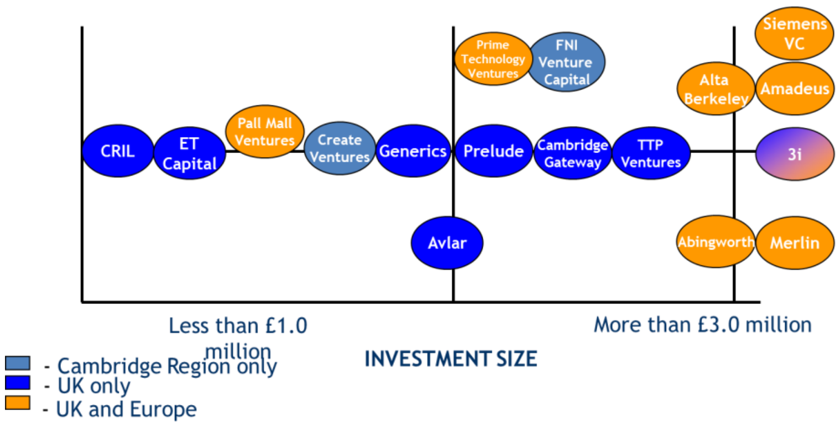


Fig. 43 Financing *(VCs)* of the technology clusters *(source:* PACEC / EEDA report 2005).

In total, the estimated value of the funds invested on the Cambridge venture capital scene amounted to more than 1,5 billion £!
All that seed money was a great help for starting up new ventures. There was nothing alike in the French cluster where most of the companies were funded by love money mainly.

And even if the figures for the French cluster are far from bad, as we already mentioned; and as we can confirm when looking into details.

Company Turnover (K€)	Y1	Y2	Y3	Y4	Y5
Jason	102	76	83	99	263
Adaje	2500	2068	1556	1469	2012
Ardeje	121	102	329	499	229
APS	307	610	1532	2200	3085
Osmooze	22	137	263	560	450
Imaje	151	1525	5336	8994	10976
Ethersial	0	4	9	19	3
Average Cluster's Turnover	**458**	**646**	**1301**	**1977**	**2431**
Average Cluster's Turnover without Parent	**509**	**500**	**629**	**808**	**1007**

Company EBITDA (K€)	Y1	Y2	Y3	Y4	Y5
Jason	-17	23	15	6	13
Adaje	500	560	169	63	136
Ardeje	8	6	51	72	-11
APS	-150	0	80	150	300
Osmooze	-100	-373	-500	-500	-500
Imaje	-5	290	1570	2210	1524
Ethersial	-17	-4	0	2	-12
Average Cluster's EBITDA	**31**	**72**	**198**	**286**	**207**
Average Cluster's EBITDA without Parent	**37**	**35**	**-31**	**-35**	**-12**

Company Headcount	Y1	Y2	Y3	Y4	Y5
Jason	2	1	1	2	5
Adaje	6	7	7	8	9
Ardeje	3	5	7	8	8
APS	4	5	8	12	13
Osmooze	1	5	5	4	4
Imaje	8	32	60	100	160
Ethersial	1	1	1	1	1
Average Cluster's Headcount	**4**	**8**	**13**	**19**	**29**
Average Cluster's Headcount without Parent	**3**	**4**	**5**	**6**	**7**
Imaje part in Cluster's headcount (%)	**32**	**57**	**67**	**74**	**80**

Company	date of birth	First shipment of product
Jason	end of 1994	1994
Adaje	avr-07	2007
Ardeje	end of 1997	1998
APS	end of 2000	end of 2000
Osmooze	end of 1998	2000
Imaje	1982	1982
Ethersial	2005	2006

Table 13 – Series of Synthetic Data on the French cluster

Besides, when we compare the two clusters, we understand and clearly establish that, by “nature”, CCl as a parent company was (a lot) more supportive to its spinoffs than Imaje for its.

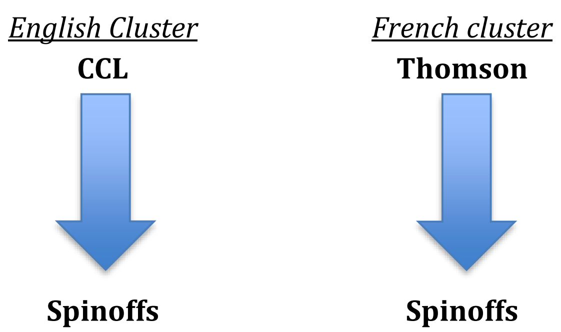
This is true in terms of investments and money; this is true in terms of operational support as well.
But this is also true in terms of technical and scientific support.
Indeed, the spinoffs from Cambridge were helped by the technical creativity and discoveries from Cambridge University but from CCL engineers too.
Trying to be complete in our analysis, we have to mention that in the case of the French cluster, a technical and scientific support to Imaje’s spinoffs was coming from contracts with an engineering school in Valence called Esisar and belonging to Joseph Fournier University and INPG group.

That is how a kind of technical and scientific expertise in microfluidics spread out in the whole cluster. As a consequence, any company was in a position to get easy access to these capabilities.

2.3.3 Findings: A new version of history

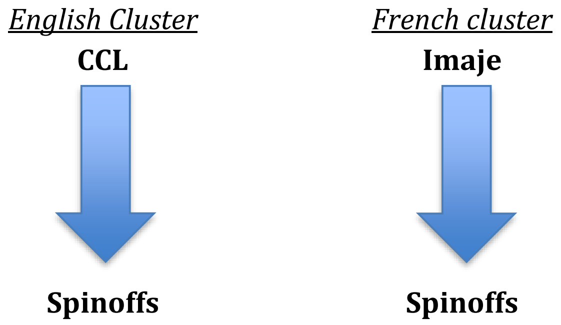
a. Imaje = CCL!

In the case of the ink jet cluster in France, the history of Thomson group is anecdotal.
That led us to consider that Imaje was equivalent in terms of role played to CCL for the English cluster.
So we modified the initial representation accordingly:
Representation at origin:



As equivalent roles were played by CCL and Imaje in their respective clusters, we decided to consider Imaje and no more Thomson at the same level than CCL in the genealogical process:

Representation with structural equivalents:



Then having CCL = Imaje, we have also CCL's spinoffs = Imaje's spinoffs.

As a result we were considering two parents companies having directly given birth to several spinoffs.
And Thomson was to be seen as a pure industrial actor.

What we have done: To describe the clusters, we started from the various bounds existing between companies in the same cluster.
We have made appear a strong entrepreneurial dimension in the two clusters.
We have also unfolded the linkage relating the two clusters from a technological- and from an entrepreneurial standpoint.

2.3.4 Expert comments to validate the revision and new version of history.

We made the hypothesis of a potential error in the history of technology.
This overall error was to consider evolution as linear; an error covering and inducing several false conclusions.
What are these undue approaches?

- A bush and not a scale.
- Confusing technologies.
- Connection between clusters (sources of technology).
- Disruption seen where there is no.
- Bond disruption / performance.

This is the very list of points that we develop underneath.

2.3.4.1 *A bush and not a scale: ASABA.*

Considering evolution on the model of a scale rather than on the shape of a bush is a first reason leading to false conclusions about innovation.

It appears through several errors coming from wrong considerations:

- First the fact that one is often only seeing the biggest branch of the technology tree. Hence what is true to the dominant design seems to be generally true for the technology as a whole; what leads constantly to a ***confirmation bias***.

- Moreover, the various stages in the technological evolution do not succeed to each other without crossings, road forks and other bifurcations. A reverse consideration would lead to a ***simplification error.***
- In addition then**,** the technology, from far, always seems to be simple, but it is not. For at this level, Devil is well in details***; what leads again to simplification errors.***

Let us now work on an example of the technology evolution presented as a scale.

In the following scheme (Clymer and Asaba, S. (2008): A new approach for understanding dominant design: The Case of ink-jet printer) we see quite clearly:

- The idea of a continuous linear improvement.
- The idea of a simple curse.

Even the path (periods of 4 years) chosen for the scale could lead to think that every four years something happens …

But the actual evolution (for this technology and others) is neither a continuous improvement nor rather a simple process. The evolution is not linear:

What the scheme is referring to is the evolution of a single branch of the technological tree: every comment limits to DOD heads for mostly SOHO applications with water-based inks!!!

But as this branch of the technology was maturing, it was also becoming more and more complex, new applications suddenly starting with the new possibilities offered. This was the case with the introduction for example of photo quality DOD printers in the second part of the 1990s.
Meanwhile, other important possibilities to print pictures were offered with the high definition standards obtained by devices using UV curing for large format printing. A branch even not mentioned in the studied evolution scheme.
So the evolution of the technology is much more complex than suggested by such a scheme: With moments of applications bursts, with some deadlocks and the creation of new branches and, as a whole, a far more complex network of interrelated technologies/applications.

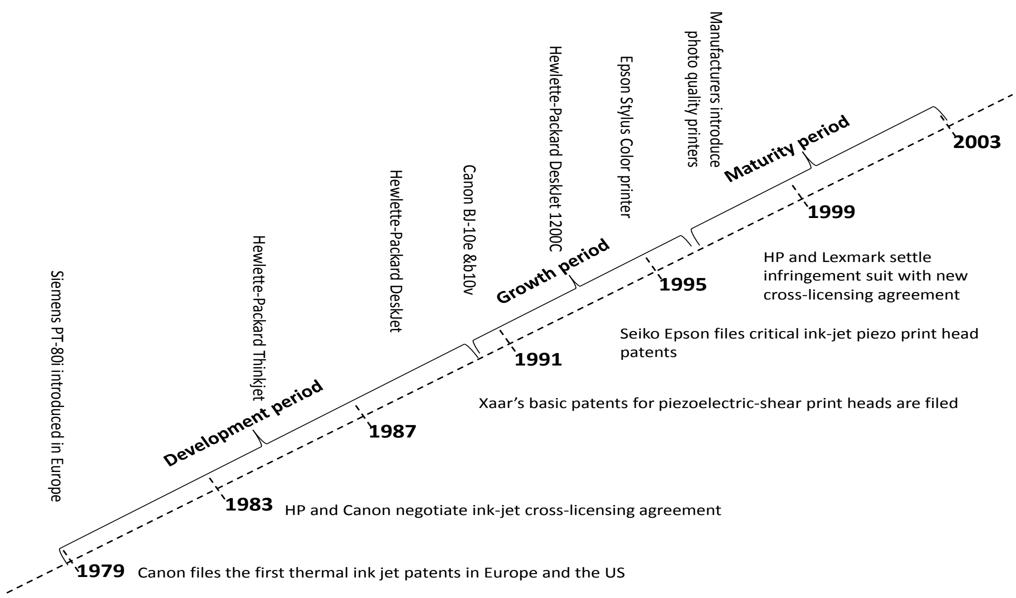


Fig. 44. Three time periods of technological and market development in the ink-jet printer industry, (Clymer and Asaba 2008, p.140). **Technology's evolution with a "moderate slope".**

In a nutshell, we understand that several aspects in the design of the scheme are inferring the idea of constant and rather regular improvement.

Throw in that the original scheme shows a steeper slope, and it becomes still clearer that consciously or not, the author promotes his conviction that the technology is constantly and intrinsically improving.

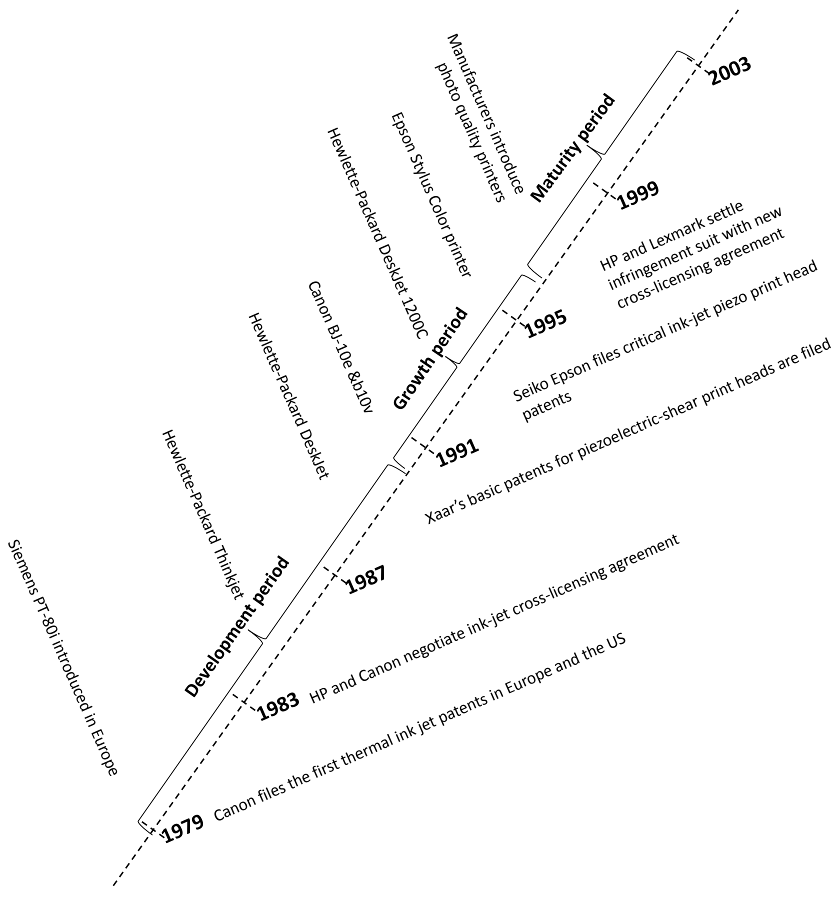


Fig. 45. Three time periods of technological and market development in the ink-jet printer industry, (Clymer and Asaba 2008, p.140) **Technology's evolution with the «real» slope.**

Beyond the facts that Industrial applications (coding) are not appearing (!) in these figures, that neither the revolutionary HP Thinkjet nor the company Seiren (Japanese printing heads for fabrics printing) are mentioned, we want to insist on the SLOPE.
What we mention as the "real slope" is the one as it appears in the original articles.
The steady upwards orientation is very common in evolutionary visions considering an ongoing progress. They reveal an unconscious belief in a continuous improvement of technology.

That leads to the following comparison scheme of the inkjet evolution path exposed twofold:

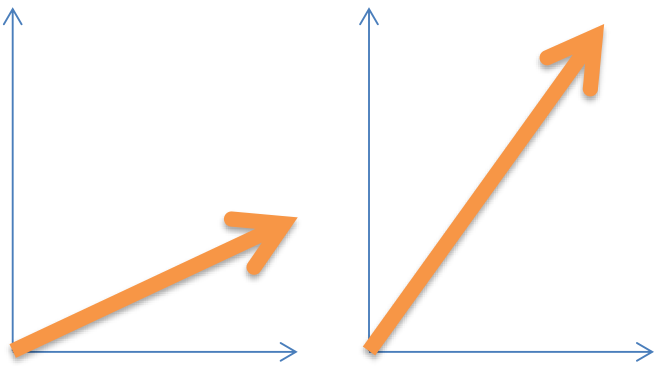


Fig. 50. Inkjet printer industry evolution over time. **Technology's evolution with a "moderate slope" VS Technology's evolution with the «real» slope**

The left draft illustrates the slope associated to inkjet industry evolution, as initially presented in the dissertation (Linearity and variations p.45).
The right draft is giving the exact slope as it appears in the article in reference. The design is speaking for itself.
The direction of the arrow supports the idea of a one way evolution, a kind of destiny for this technology to improve overtime.

But our position is to consider that, even if the technology is somewhat improving:

1- This improvement is not constant or at least not linear:

New possibilities offered by a brand new version of the technology are most of the time a new balance between criteria that were pre-existing. So the word improvement is a pitfall. It does not bring to light the real process behind a novel technological option: What is changing most is the hierarchy of criteria used for choosing a technical solution.

If you consider for example that an expiry date on a bottle of water must be easily visible you will certainly choose an ink jet solution to mark rather than laser.

But if you consider that low running costs are a priority regardless of the visibility of the print, you could choose a laser solution: Whatever the print quality of the most updated ink jet printers could be.

New equilibriums in the purchasing criteria also lead products to fail and complete technological branches to disappear.
When in 1992 at Drupa (Germany), an Israeli company made the buzz around a futuristic full color printer online, many were thinking that continuous ink jet had broaden its scope immensely.
But nobody ten years after was mentioning any more this technological option as a potential breakthrough. It was an impasse and a dead branch in the ink jet technological tree.

What happened?

Customers were expecting full colour on line at fast speed. And for that, the solution was OK.

But there are thresholds in terms of buying criteria. And unfortunately for the instigators of the solution in question, reliability and quality consistency were prominent criteria not matched by CIJ print bars (if not binary!) at the time.

Branches can disappear. But new promising products can fail as well.

When Imaje S.A. developed its JAIME bus product enabling to print with the same core printer on different and separated production lines, the products managers were convinced of the attractiveness of the solution. For many customers were really interested by multi heads solutions for multiple production lines. They were expecting a convenient solution combining the multiple heads with one sole cabinet and one sole keyboard.
The product was a complete failure. Because in case of breakdown (root cause), the production casualties were as a matter of fact multiplied; and that was overpassing the interest of a multi tasks machine.
As mentioned previously, the hierarchy of buying criteria and its evolution are affecting the potential success of technological enhancements and of new products.

These elements reinforce the idea that favourable points of difference in a value proposition are changing. Using the taxonomy of *Anderson, Narus & van Rossum (2006),* we understand that new options should consider less "what is good" than "what is best".
Whatever could be the kind of value proposition considered between "All Benefits", "Favourable Points of Difference" or "Resonating Focus".

2- The so-called improvement is mainly leading to fulfilling the needs of specific niches rather than enlarging the scope of the technology.
The enlargement of the scope is coming from new versions derived from the same basic principles. New market niches are thus appearing in the old scope because new specific features are enhanced on existing products.

When Jason Company launched, in 1997, its printer targeting mainly the egg industry, it was a success. It was not an "improvement of the technology" though.
For the technology used was already really common for years; but not in *this* industry.
The result was that all the trials from CIJ competition (incumbents) to reconquer the market share occupied by Jason were vain.
They tried to release low cost CIJ printers.
But the lowest affordability remained in favor of Jason, keeping to satisfying the customers' segment it has created.

In short, we are facing two cases:

1- Evolution of the technology within the existing "scope" of applications.

2- Technological Breakthrough.

This dissertation is reaching the point where one of my favorite problematic arises: The problem of layers.
Layers, layers, layers… Layers of technology; and also layers of applications.

If we look at the CIJ / SCP inkjet heads that can be equipped with **two drop generators** instead of just one: We do not change the basic DOD / continuous jet (technology layer) difference. However there is a strong impact on the CIJ subfamily that now has an additional member (technology layer again).
Besides and as far as the *application* layers, this time, are concerned, this new feature does not change the fundamental CIJ targets: agro-food, pharmaceutical industries …. But it offers these applications new possibilities (application layer): marking more lines with just one head, doing bigger logos or barcodes ….
Hence an additional advantage in representing the technical evolution as a tree or a bush, but not as a ladder.

2.3.4.2 *Confusing technologies …what leads to false conclusions.*

Let us take an example to illustrate this point: When Garnsey is writing "Incumbent firms were stretched by the home and office printer markets and left a product identification market to new entrants" (Garnsey, Thomas, Stam; University of Cambridge / Centre for Technology Management, 2009)…. This assessment is false.

Why? Because the product identification market was requiring a technology fundamentally different from the one used by incumbents on the desktop market.
In short, the technologies were so different that today (30 years after the emergence of the coding market) the overlap between their respective fields of application is still very limited.
The desktop market is basically favoring ink jet heads using water-based inks (to print on porous substrates, paper) at low speed.
When the product identification market requires "solvent" inks to stick to the various substrates and print heads adapted to aggressive liquids. Not to mention the speed that can overpass 3 meters / second (see p.22).

So there is very few in common, at technology level, when we compare these 2 fields of application.
This kind of errors is rather frequent, though.
For, beyond some common principles, the *technology bush* can be very confusing with the many variations of its numerous branches …
So the risk to oversimplify the picture is permanent.
Plus the fact that it is very easy to mismatch a technology for another.

Hence the trap is ready through a combination between *mimetic illusion* errors and *confirmation errors (D. Kahneman, 2011)*.

After hearing, for instance, so many times about DOD technology to print on paper sheets, DOD to print on primary packaging, DOD to print on corrugated boxes… It is easy then to confuse all these applications and to consider that the same technology is at stake.

Of course, if DOD only means one nozzle per dot. That is right!
But this vision of the technology is too generic to put into light the necessary understanding of the differences.
The problem is that, without this understanding, no true conclusion could be drawn neither on a potential disruption between two maturity levels of a technology nor in terms of how a new technology is fitting an application.

Bad technology understanding leads to false conclusions on innovation management. Innovation management principles are influencing innovation practices.
So bad technology understanding leads to bad innovation management practices.

2.3.4.3 *Connection between the clusters (as sources of technology) :*

At the beginning of this work, we were convinced that the English cluster and the French clusters were independent.
We knew that the 2 clusters had started because of the potential offered by the CIJ technology. But we had no question about a potential bond between the two.
For us, these sources of technology were just appearing almost in parallel, obviously in more or less direct relation with what had emerged in the US and specifically in Standford with the works of Dr. Sweet in the sixties.
But again, nothing brought to consider any influence between the two research groups.

They appear as independent … and they are not! (See also Table 2)

In addition to what we mentioned previously (p.64), not only were they connected from the very early stage.
If cognitive bias is considered to affect behaviours in economics and leading to anomalies, they also affect management research.
And this case is a significant example of an availability bias.
A kind of error based on the fact that people (and searchers) do not usually look for more pieces of information than the ones available.
It is a statement in absolute accordance with the works of Daniel Kahneman, who received the Nobel Prize in economics in 2002.
As far as the two inkjet clusters are concerned, none of the papers describing the emergence of the English cluster is mentioning a linkage with the French cluster at origin.

And conversely, when we interviewed the entrepreneurs in the French cluster, these founders of Imaje's spinoffs did not spontaneously refer to early collaborations with the technology centre in Cambridge.

The link is well existing, though.
Indeed, we learned that not only there was a link at origin between the 2 clusters, but we also learned that this bond was moreover very significant and useful for the 2 clusters.
The corresponding information was brought by the experts interviewed in the framework of this dissertation.
And it is to be noticed that the piece of information appeared to be *confidential;* at least partly.
The experts were aware of the "common" origin of the 2 clusters.
But only one of them had all the details about the whole story.

First, all the experts did know that Thomson group (in France) subcontracted almost the entire inkjet project to CCL (in UK). For CCL had acquired a previous experience by working on another project (for CCI, cf. above).

Then, the experts were also informed that, in return, CCL and hence Domino had benefited from the developments operated for Thomson / Imaje. One proof of that can be seen in the fact that the initial CCL team having contributed to the French cluster, was gathering numerous future promoters of the ink jet technology: Ellen Pullen, Mike Kealing, …. not to mention Graeme Minto, who was project manager.

Besides, at least two facts were hidden in the history of the two clusters.
We have thus discovered that:
- Imaje first started as a distributor of Domino printers! This is the proof of strong bonds between the 2 leading ink jet companies in Europe at that time. But very few people and no scholar seem to be aware of it.
As the official history of ink jet is NOT mentioning that Imaje was exhibiting Domino products when taking part, as a newly incorporated company, to its first trade show.
And if Imaje became soon a real manufacturer, abandoning the distribution of Domino's devices, perhaps can we see in this decision the initial reason for the kind of durable "hatred" towards Imaje from Domino and Cambridge people. An animosity that cannot easily be explained some other way.

- A second unknown piece of information - so far - about the linkage between the French and the English ink jet clusters is referring to technics.
Indeed, among other mistakes frequently impacting the development of a startup, Imaje underestimated the importance of a technical parameter.
Namely, in this case, the definition of raster data was too simplistic.
This critical aspect – conditioning the interactions between droplets - was clearly underdeveloped by Imaje development engineers.
The algorithms enabling to pilot the tensions affecting the charged drops were poor compared to Domino's.

Remember that the Domino team had a real experience of inkjet when the technical manager of the original Imaje team had work on thermal printers (Contactless Thermal Direct) only.
Moreover, the Domino team had an experience of the specification of objectives for the Fax application that were far superior and demanding to the ones necessary for coding. As a consequence, the monitoring of the drops' flow constituted a weak point for Imaje printers.

The necessary improvement at this level was later on subcontracted by Imaje to CCL!
These facts are highlighting the importance of previous experience at technical development level, in a kind of "Technical Path Dependency".
A concept borrowed from the Path Dependency in economics and technology.
In this case, it is not only the fact that initial technical decisions and investments are conditioning the future choices.

More precisely here, we state how the initial experience of a technology is impacting the manner and the degree of requirement that will be applied to the future projects.

In a nutshell, and more generally, we have established that the 2 clusters were not independent from the very early days of their emergence.
What most of the analysts do not reveal.

But let consider the rare papers showing an existing link between the technology developed in Valence and the one having emerged in England.
When the link between clusters is mentioned.

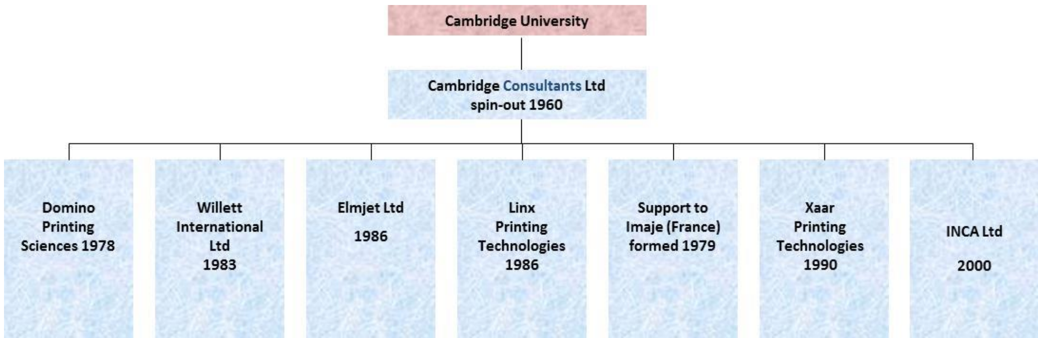


Fig. 46 Industrial Inkjet in Cambridge (Source: PACEK / EEDA 2005)

As we can see on the scheme above, established by the East of England Development Agency for the Cambridgeshire County Council, the link between the 2 clusters is well mentioned. But it refers to the French cluster just through a mere “support to Imaje (France) formed 1979”.

In fact the reality of the cluster in France is simply not considered.
So the bond between the clusters is simplified, limited to something anecdotal.
Again an error. A cognitive bias called *simplification error*. As there is no apparently significant relationship between the two clusters, everyone progressively tends to consider that there is no relationship at all.
A bias that N. Taleb puts it the following way in his book *Antifragile* referring thus to a general scientific statement : “the evidence of absence is not an absence of evidence”!

Additional types of cognitive biases are attached to the “old version” of industrial inkjet history that we analyze. To illustrate this point, do consider the concept of disruption so often associated with the inkjet technology development.

2.3.4.3.1 Disruption seen where there is no.

In many instances, disruption is associated with inkjet. But this association is regularly invalid.

Just look at the following situation:
When in the second part of the 1980s, Imaje developed the use of multiple printheads in ink jet printers, observers were considering it as a product disruption. The so-called Jaime Bus enabled, indeed, to print at the same time, and for the first time, on different production lines or more than two lines on the same product.
The design of the Jaime Bus was in fact organized around one single cabinet monitoring up to 4 printheads.

But this product was very complex and not offering a sufficient reliability. Throw in the fact that industrials were reluctant to risk to stop several production lines in case of breakdown (rather than only one), and you understand the pitfall having killed this product, as already suggested.
We can then conclude on the absence of proven disruption in such a case.
For the value created on some emergent criteria did not enable to overcompensate the deficiencies contained in this new solution.

The qualification of disruption is also abusive as far as “the use of multiple printheads” to develop the billing and addressing markets is concerned (see below and see Ford et al., 2011).

2.3.4.3.2 DOD was disrupting CIJ

This point was clearly mentioned as a fact by Ford (Ford et al. 2011) He indicates that DOD technologies have emerged “in the early 1990s” (page 3 ibid.). He is also drawing an opposition between CIJ considered “at the mature stage” when DOD “still have … to mature”, thus describing an “evolutionary path”.

But there is NO evolutionary path between the 2 technologies!

As we undoubtedly stated it (cf. the chapter “Technology and Performance), the evolutions of the two technologies were (almost) synchronic.
Indeed the first CIJ printer – The IBM 4640 - was released by IBM in 1976.
When the first DOD printing system was launched no more than one single year later with the Siemens PT-80 (released in 1977).
So that happened more than 10 years before the 1990s.

In fact, these types of examples are rather common among the literature about disruption and technology.
For the understanding of the technology considered and its evolution seems to be generally insufficient.
As already mentioned, qualifying a disruption implies taking into account not only the technology itself. Indeed, as far as innovation is concerned, a technological difference or newness is not enough to qualify the disruption.
For the creativity in technique is permanent. And many enhancements in technique are just leading to pure “technical things”, without sufficient user value.
The list is long, in all the company surveyed, list of products abandoned because of that.

So, if a technological difference or newness is not enough to qualify the disruption, what is missing?
We understand that the disruption appears at market level.
But market is a broad word and technology too!
The concept enabling to mix the two variables of technology and market is called *application*.
The disruption makes it visible when a novelty in technology ***applied*** to a market impacts radically the value for customers.
The problem is then to qualify what an application is.
Here, the *fractal nature of markets* (B. Mandelbrot and al. 2004) plays a role.
For a disruption can occur at any level (“layer”) of a segmentation tree!
What we show through the following example:

Level of disruption (layers)	Level of Application (layers)
activity	Coding
Sector	Agro-Food
Product Family	Dairy Products
Item	Secondary Packaging
Substrate	Porous
Speed	Low Speed

Table 14 - Example of an application offering several potential layers for disruption

We can observe disruption at different levels *independently*. It means that a disruption observed in the first layer (in this case “activity”) can be invisible at item level (4th layer), for instance.

Said otherwise, a disruption affecting Coding Activities can be disruptive for individual products ***and not*** for secondary packaging ***or not*** for all kinds of secondary packaging targeted by coding activities.

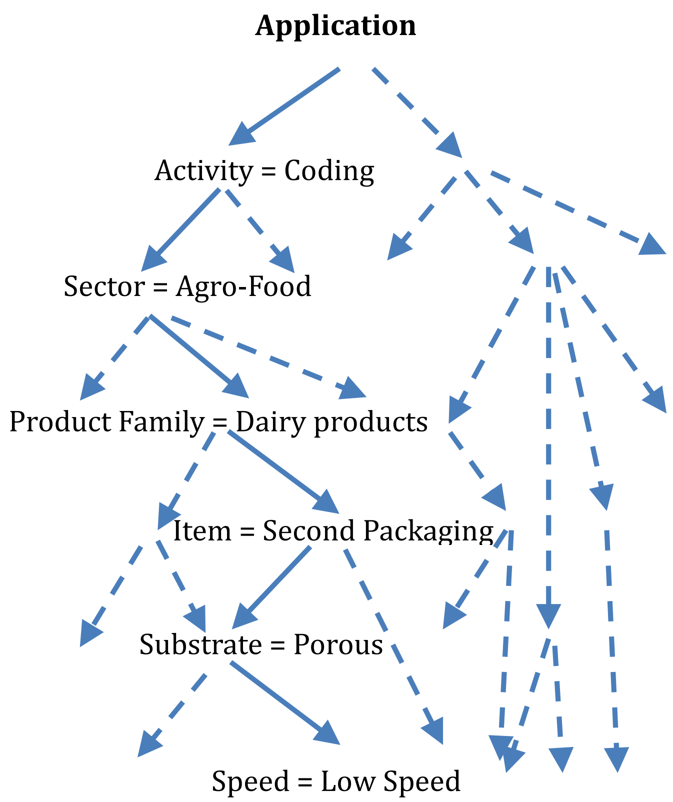
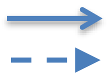


Fig. 47 Levels / layers of disruption according to application levels. Example of a segmentation tree.



Application Path

Potential Application Path

So the bias we were mentioning at the beginning of this chapter can be described the following way: when two situations seem the same, observers sometimes falsely conclude that they are!

Most of the time, the error is coming from the fact that what is actually similar at one application level is not similar when you consider all the levels (LAYERS) of a specified market.
For example: DOD heads with water-based inks were not disruptive when considering to implementing this solution in the framework of coding agro-food packaging.
For the coding market as a whole (in the food sector) was mainly expecting fast speed solutions to print on plastic or filmed carton mostly.
But, on reverse, these same DOD heads with the same water-based inks were well disruptive to print on items such as carton boxes for eggs (porous substrates), at low speed!
This cognitive bias bears the name of *mimetic illusion.* It happens when you misunderstand that two situations are different when you think they are the same.
For one has to take into account all the parameters describing an application. But these parameters can be very numerous and specific!
Moreover, and to conclude on this part, the very combination of criteria can be / is specific to one application.

Thus, criteria as "Speed and Print Definition" can be problematic if the target is coding on (most) *primary packaging*; when, on the contrary, they are **not** problematic if the target is to jet on (most*) grouping cartons*!
Users are indeed expecting a print quality for packaging *they can see in shops* (primary packaging).
But they are not generally interested (and marketers neither), of a print quality on grouping cartons *used for single logistic purposes*.
The reasoning is the same for the speed criterion: primary packaging can be processed at high speed in plants (bottling facilities e.g.), when grouping cartons mostly transit at low speed (typically at less than 1m/s).

2.3.4.3.3 Bond disruption / performance :

As we have established it in the previous paragraphs, sometimes the history of ink jet indicates technological disruption when there is not.
But some other errors can be found when we consider the bond between disruption and performance.
Two kinds of errors are appearing:

- ***Confirmation errors:*** One sees the Disruption / One then conclude on the Performance.
- ***Generalization errors:*** A question of layers … once more.
  Observing from « too far », the vision is all but very general: One can see the average performance, and then conclude on the performance of the entities, whereas the variations are strong within a sample.

We consider that, in the case of microfluidics technologies, some errors are explaining most of the doubtful affirmations on their history.
These errors are mostly errors of logics (in the sense of Aristotle).
These errors are rather common as far as innovation is concerned.
And theoreticians like Gould or Taleb are familiar with them.

The false affirmations relate to a small number of frequent inadequate inferences.

This refers again to the general assumption that puts it: "The evidence of absence is not an absence of evidence". A phrase highlighting the general reasoning issue between the reality "in front of us" and probabilities or chance …
Something that we can illustrate with 2 realities:

1- When one sees an event, he/she tends to overestimate the probability of occurrence.
2- Conversely, one underestimates most of the time the probability of occurrence of rare events.

We made the hypothesis about potential such errors in the history of microfluidics technology.

As a consequence, interviews with 2 experts were conducted at the end of our qualitative research to check:

- The validity of the new version of history (if any).
- And the validity of the other findings.

Potential adjustments in the writing of the 2 case studies were to be enhanced after experts' comments.
In addition, and If possible, a quick survey to ultimately corroborate the findings was planned. It targeted the third industrial ink jet cluster in the US (Chicago).
For that purpose an interview was conducted in Atlanta with an ink jet specialist.
He was the one who told us that the microfluidics technical bases were scattered all over the US.
Indeed, when Spectra started in Darmouth (New Hampshire), Marsh and Diagraph developed near St Louis (Missouri), Kodak in Dayton (CIJ) and Rochester (TIJ), HP in San Diego…
Videojet, the original American leader in SCP, for its part, based near Chicago, was modernized by Helen Pullen from Cambridge (U.K.!), but, as already stated, never contributed to a clustering of companies around its core facilities.

In the discussion, it was instead interesting to notice that our expert was considering spontaneously Valve Jet technology as "an extinct species" (cf. chapter linearity and variations, above).

2.3.5 Tentative Conclusions about the 2 case studies.

We have encountered several pitfalls while digging into data about the 2 clusters.
Three main issues have occurred:

- The various authors, experts and scholars do not tell the same story.
- The secondary data are not homogeneous with the direct collection of information on the theme of performance.
- An issue was also to show the uncoupling between performance and presumed disruption from a company.

Nevertheless, a series of conclusions can be stated on the basis of the 2 clusters' analysis.

2.3.5.1 *About the U.K. ink jet cluster:*

In opposition to what is generally said about the Cambridgeshire cluster: CCL and its spinoffs didn't actually take part to the development of the ink jet technology as a whole. At least, not at a very large scale.
And this, in opposition to what is written about the "Major market share participation worldwide" of the cluster in England for the Cambidgeshire Council (PACEC/EEDA official report 2005).

The technological enhancements coming from this cluster were indeed mainly related to the single branch of CIJ. But CIJ is *one sole branch* among the whole gamut of ink jet printers' categories.
The proof of it can be seen in a single figure: More than 50% of the employment and turnover (more than 3000 jobs in total and revenues in excess of 500m pounds per annum) in the cluster (Garnsey 2009, p.7 and p.10 & J. Thompson 2009) was thus coming from companies in the cluster manufacturing CIJ printers. **And this statement was valid at any time during the period surveyed: 1978 – 2008!**
But even if the CIJ was undoubtedly gathering the majority of the wealth-benefits coming from the technological innovation in the Cambridge cluster, some nuggets of startups have emerged from the UK IJP cluster; and companies that were using other sub-technologies than CIJ.
This is the case for example of INCA digital with its flatbed printers that were targeting "true" printing- and not coding applications.

Nevertheless, the fact that INCA digital was never breaking even before its takeover by Danaher leads to consider the limits of innovation for growth in the cluster outside the CIJ technology!!

2.3.5.2 *About the ink jet cluster in France:*

The French IJP cluster also contributed to the emergence and importance of CIJ technology. Even if this occurred at a smaller scale (1 isolated juggernaut) than in UK (3 international players having started from scratch).
In fact, no other company than IMAJE could be seen as a kind of industrial leader.
And there was no internationally successful company in the French cluster, except IMAJE and APS.
APS case is really specific.[12]
For it is just surprising that the only greatly performing spinoff in the French cluster, namely APS, was a mere distributor when starting.

What can explain that?
Most of the traditional academic reasons explaining spinoff performance can apply to APS: experience of the founder, complementarity of the team at high level, significant funding ….
But the prominent reason for this success is to be found elsewhere according to our thesis.
And the reason for this big success is just thoroughly related to the limited, even if real, commercial success of the majority of companies surveyed in both the UK and the French clusters.
To evaluate the odds of equal or superior success of a spinoff in comparison with the parent company, one can refer to the well-known traditional performance criteria. These sets of criteria, "predictors of innovation success" (B.Heeley and R. Jacobson, 2008) can be seen as general things like: the ability to differentiate from competitors or the ability to bring disruptive innovations on the market.

But it is not enough. As are not explanatory enough the usual performance criteria for new and small ventures (Cooper, 1993. Haber, Sigal and al, 2005). For, according to our findings, the "STRENGTH" of the original solution (solution understood as an offering) has to be taken into account. The meaning of this strength concept is commented in the next chapter.

2.3.5.3 *Conclusions on performance of high tech spinoffs*

In the framework of clusters, if we refer to ordinary reasons for performance, 3 sets of criteria can be established as far as genealogy is involved:

- Reasons linked to entrepreneurial logic: The man in charge! (Vesper 1980; Low and MacMillan 1988; Cooper and Gimeno-Gascon 1992).
- The bond with the parent company, if any (Franco & Filson 2006; Klepper 2001; Klepper 2007).
- The way the venture positions itself among the cluster (alliances … Afuah and Tucci 2003; Garnsey et al. 2008; Ford et al. 2010).

On our side, we first studied performance in the 2 clusters by considering the dynamics of actors that had founded ink jet companies.
For this purpose, we elaborated a taxonomy based on priority levers actioned by the entrepreneurs (see Fig. 48 below).
This taxonomy is confronting Strategy vs Business Acumen on the one hand and Technology vs Wealth on the other.
Did the firms surveyed base their development mostly on Wealth? That would have highlighted the importance, for example, of seed money in performance.
Did entrepreneurs suggest that they expected the success to derive more from technological enhancements?
Did they have a precise plan before starting or did they for the most part count on their talent for business?
Each one of these issues was a long way from being independent of the others.
But all these questions are well covered by previous research. And nothing new was emerging from our clusters' inquiry.

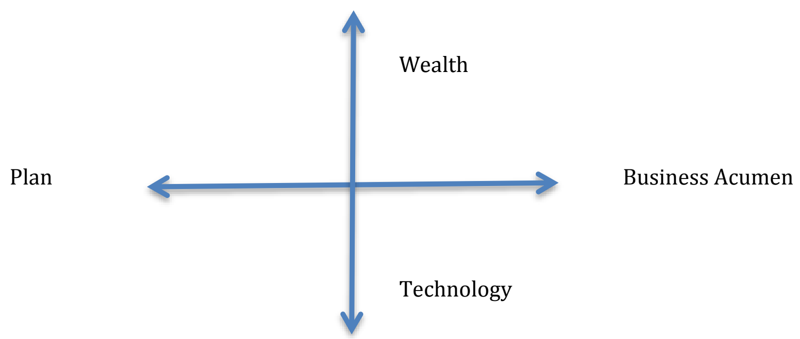


Fig. 48 Performance's priority levers

Similarly, we questioned the link between the initial reasons for spinning off and their consequences on the new ventures' performance.
It was what led us to validate the results of previous research on the topic (Klepper, 2001): the initial reasons for spinning off are short to explain the new venture's performance.
We also underlined that when comparing the 2 clusters, the importance of a good understanding of the technology involved to make real differences appear.
The point was to highlight how CIJ, among all the varieties of ink jet technologies, had specifically been a driver of success (performance) for companies.

So it is not surprising to notice, as far as CIJ is regarded, that the 2 dominant companies in the European ink jet clusters (Domino and Imaje) were competitors competing head to head; with each one gathering around 30 % of the world market.

Even though we saw that the majority of the companies in the cluster developed, we can also identify differences and specific cases that the traditional underlying factors fall short of being able to clarify.
Our work sits at the crossroads of a number of research avenues.
Namely, the studies that examine:

- The emergence of industrial clusters, particularly those that highlight the role of a « parent company ».
- Thematic similarity in innovation, especially technology innovation.
- The « predictors of new venture performance ».

As far as the emergence and development of clusters are concerned, there are numerous references both in the dynamics that support the development of technology clusters (Ford et al. 2011), and in the lineage and the relationships between companies in the same ecosystem (Garnsey 2009), or in the effects of geographical concentration (Owen-Smith and Powell 2004), and even in the performance of « children » from the same parent company in a cluster (Tucci, 2011).

And this list does not in any way do justice to the numerous studies that have flourished on the thematic of technology clusters and their development since Dosi's foundation articles (Technological Paradigms and Technological Trajectories, 1982) or Nelsons' (Institutions Supporting Technical Advance in Industry, 1981).
Nonetheless, these works on the seeding of an area - though highlighting the benefits of an agglomeration - did not emphasize the relative success of the anchor company and the spinoffs in this agglomeration.

In another area, the thematic similarity in innovation has led to reflection on hidden similarities (Gibbert et Hoegl 2011), false similarities in their uses (Von Hippel 2012), or even a collection of literature on « Dominant Design » (Christensen). But little has yet been written on the rather swift parallels drawn on innovation or technology that are SEEMINGLY SIMILAR!

Finally, the performance of the spinoffs in an industrial cluster emerging from a strong firm has been well defined (Klepper 2005), just like the trend of these spinoffs to outperform the other startups and to continue to exist more easily (Franco & Filson 2006, Klepper 2007).
Likewise, and in a more general way, the study of factors encouraging the performance of new companies represents a significant area of current research into entrepreneurship and innovation.
However, these studies focus mainly on 3 performance outcome possibilities:

- Failure
- Marginal Survival
- High Growth

A framework that already existed twenty or so years ago in the works of Cooper (Cooper, Gimeno-Gascon & Woo 1994).

As for us, we wish to contribute to these theoretical inputs by showing how technological choices that are ON THE FACE OF IT similar can result in markedly different performance levels between companies in the same cluster.
In this dissertation, we would particularly like to bring the existence of outliers to the fore and the consequences of their presence in a cluster's overall performance.
These outliers inaugurate a new position on the scales for measuring new ventures' performances: Hyper growth.
From a theoretical perspective, we try to identify, understand and measure the impact of outlier organizations on their ecosystems.
Indeed, the basic strategy precepts confirm the advantage of differentiation as «standing out from the crowd».
But, by dint of benchmarking and innovation, most companies nevertheless end up by looking like their competitors!
This is why it becomes very interesting academically and practically to seek inspiration from outliers, these actors with exceptional performances in their sector.

In practical terms we will show that for innovation, efficiency appears on specific technological levels. By working in the innovative sector of ink jet, we have identified various technological layers, each one slotting into the other like a collection of Russian dolls.
These variants of the same generic technology reveal a heterogeneity that explains the performance differences between companies in the same sector
We therefore wish to help managers identify the relevant levels of technological differentiation for the applications they are targeting.
This tooling completes the operational methods provided for managers and company leaders by the disruption theory. This should make it possible to improve the quality of replies to questions such as: « What kinds of innovations will appeal to certain customers and which ones will not »?
This should also make it easier to understand and predict companies' exceptional performances, as well as their ordinary (average) or insufficient performances.

The Rhône-Alps region cluster of industrial ink jet turned out to be an interesting empirical context to study the comparative performances of startups during their first few years of activity.
It is an interesting empirical framework, first of all because these companies constitute a complete sample.
They belong to the same ecosystem. Not only are they geographically close to one another but they also have Imaje as a common ancestry.
A second set of reasons that explains the choice of this cluster stems from the development of ink jet technology.
While just two main technologies have developed since the 1980s, CIJ (Continuous Ink Jet) and DOD (Drop-On-Demand), numerous branches are enriching the technology tree with sub technologies.
Yet, the ink jet cluster in France, near Valence, draws on a number of variants of the two basic technologies which should lead to providing valuable insights.
Particularly insights into the performance differences according to the technological variants chosen by the companies.

All the above comments are continuing our « fractal » approach *(LAYERS)*:

Sector → Cluster of Companies → Each Company

2.3.6 From true industrial emergence to spinoff performance

In order to study the French ink jet actors, we first identified the companies that belonged to this famous cluster and that were originally from the same industrial group.
We then built up a database over a number of years that included information on the companies and their development, the technologies that were developed and also information on the companies' founders and directors.

From the data base that we built on the basis of the 2 European clusters, we analyzed the first 5 years of activity for the various companies in the cluster:

1- First in terms of turnover for the first 5 years.
2- And the evolution of headcounts.
3- Then the EBITDA over the same 5 first years

Let's take a sample of companies belonging to one of the European clusters:
We obtain the following charts, based on calculations considering the average values in the cluster.

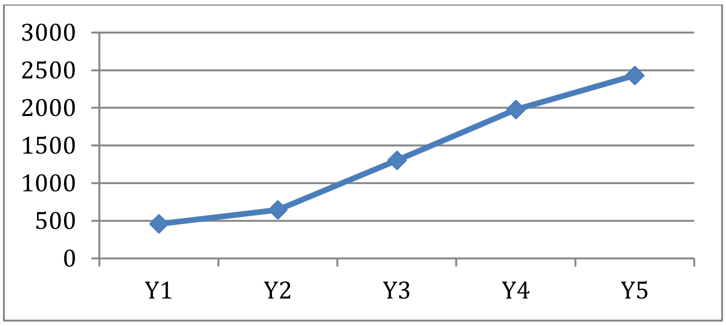


Fig. 49 Cluster's Turnover Sample 1 (K€)

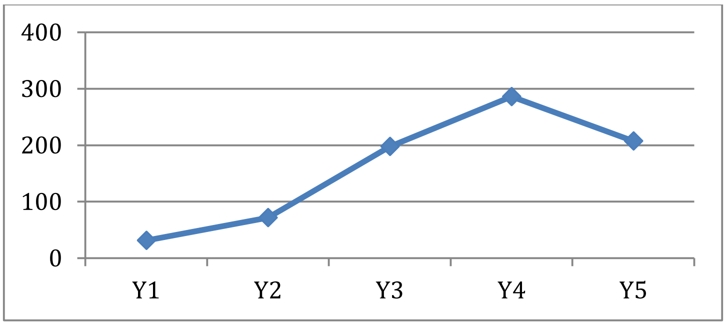


Fig. 50 Cluster's EBITDA Sample 1 (K€)

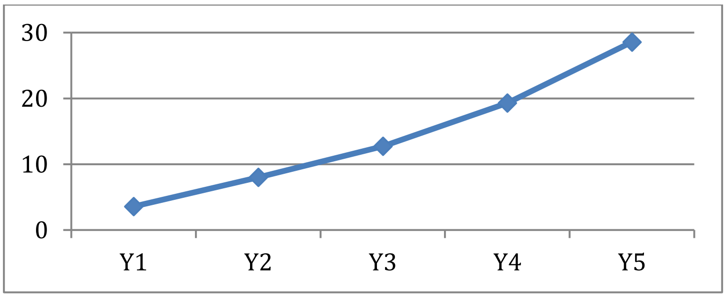


Fig. 51 Cluster's Headcount Sample 1

As can be seen from the above graphs, there really is performance!
Both in terms of revenue and increase in headcounts as well as results.
But where does this performance come from?
We have previously seen that there are layers of disruption (disruption at different levels), as well as differences in performance. Do these differences apply to the sample?

Chapter 3 - IN SEARCH FOR OUTSTANDING PERFORMANCE IN MICRO-FLUIDICS AND BEYOND

Performance of spinoffs from the same parent (zooming on the ink jet cluster in France).

3.1 Performance and Performances

3.1.1 Another sample of companies

We go back to the preceding logic:

Let's take *another sample* of companies from the same cluster.

We still evaluate the performance of firms from the same set of criteria and still consider the first 5 years after their launch:

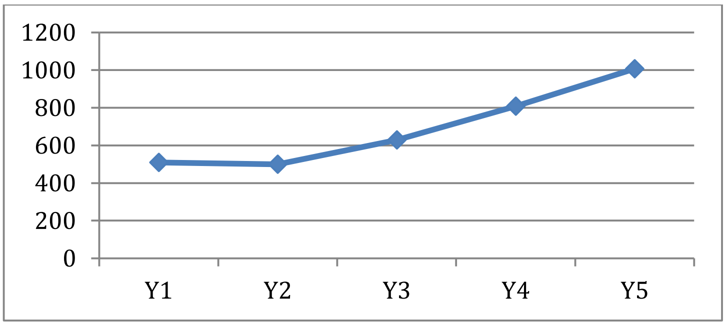


Fig. 52 Cluster's turnover/ Sample 2

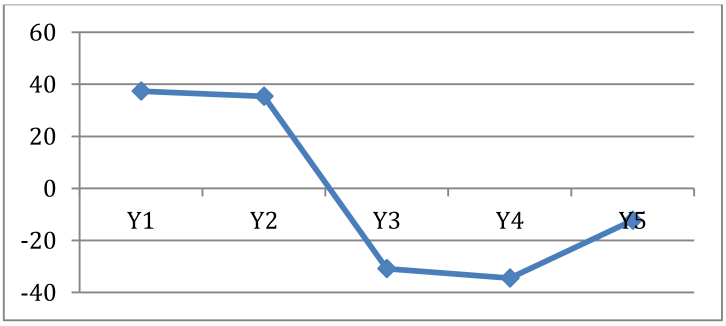


Fig. 53 Cluster's EBITDA / Sample 2

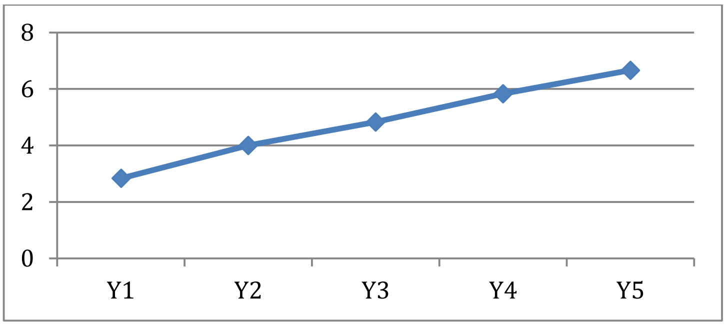


Fig. 54 Cluster's Headcount / Sample 2

Now let's put the curves attached to the 2 samples side by side to first show the similarities, if any.
In the following curves S1 stands for Sample 1 and S2 stands for Sample 2.

Curves Sample 1 **VS** **Curves Sample 2**

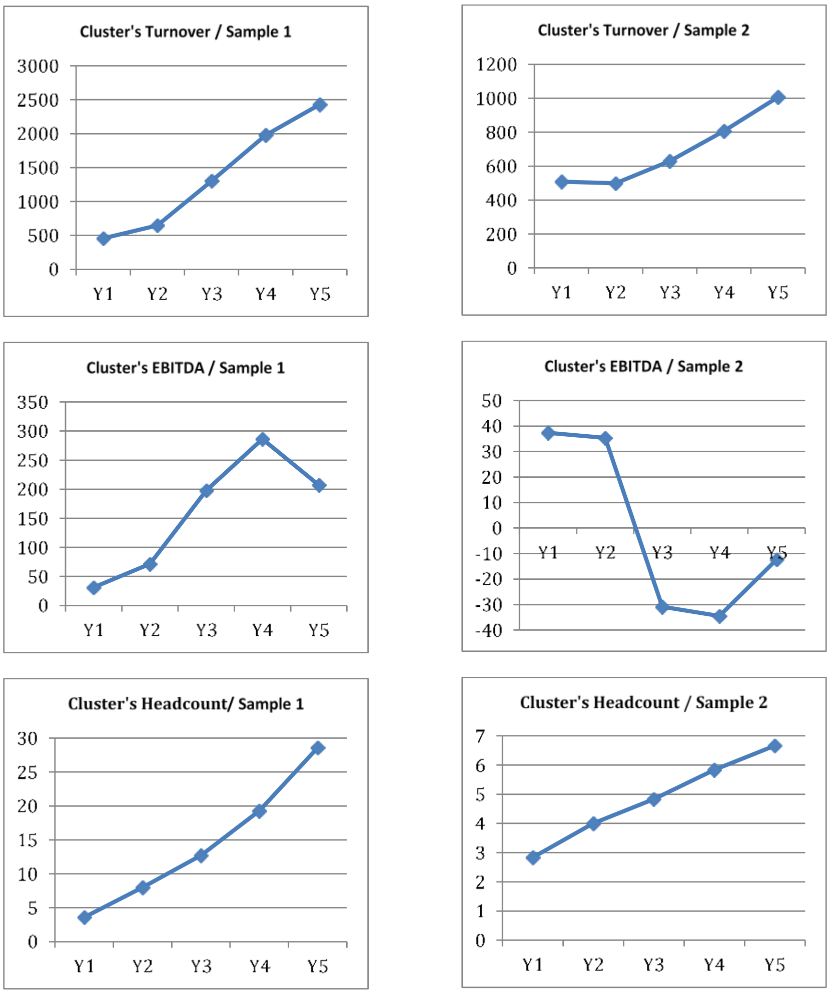


Table 15 - Comparing the 2 samples

That gives way to further compare the 2 series of curves.

Reminder: All the companies in the cluster, and then in both samples, originated from the same parent company (Imaje S.A.).

We are going to compare the 2 series of curves but we are going to do it by adding the results of the parent company to the comparison.

We are therefore going to have 3 curves for each criterion: the ones that correspond to the 2 samples and the one that corresponds to the parent company alone (Imaje S.A.). The parent company is to be used as a reference in that it will provide the scale for the 3 dimensions that have been measured (Turnover, Headcount, EBITDA).

On the basis of the parent company (French cluster), we get the following:

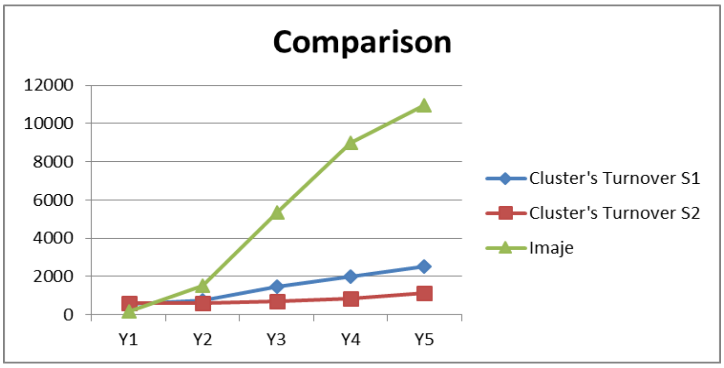


Fig. 55 Turnover comparison: Cluster vs Imaje

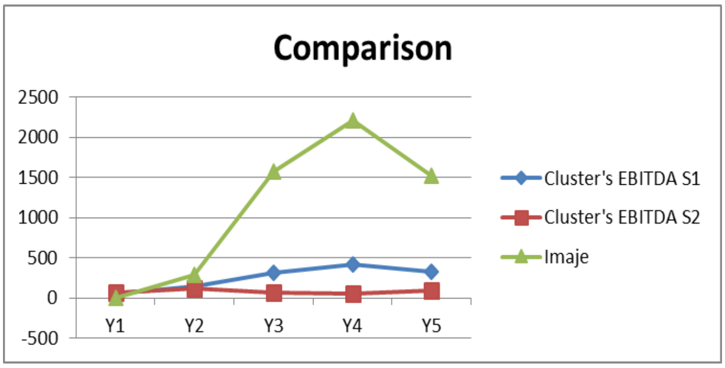


Fig. 56 EBITDA comparison: Cluster vs Imaje

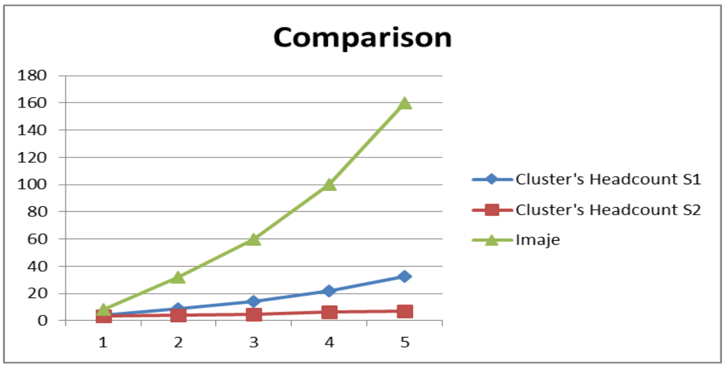


Fig. 57 Staff comparison: Cluster vs Imaje

A priori there are similarities in the 2 original series of companies (Sample 1 & Sample 2).

But the graphs also clearly show that the parent company does not have the same rate of development as the 2 startup samples.

Besides: *Differences can be seen in the performances of the 2 samples*

3.1.2 Similarities and scale effect

So let's now take the 2 curves (averages) and compare them based on another scale (i.e. another reference than the mother company)

We mentioned previously that a priori there were strong similarities between the samples. But when looking at them much closer, we find there are **big differences**! And not only at EBITDA Level.

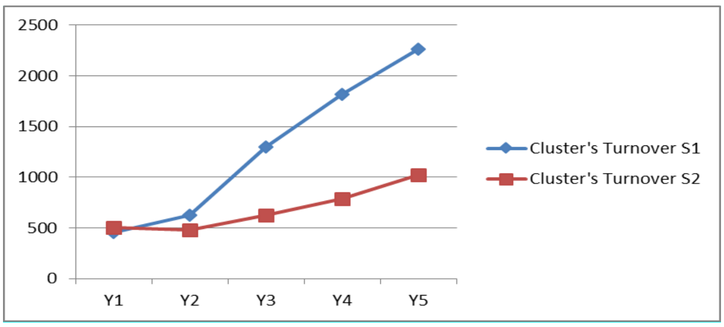


Fig. 58 Turnover comparison: Sample 1 vs Sample 2

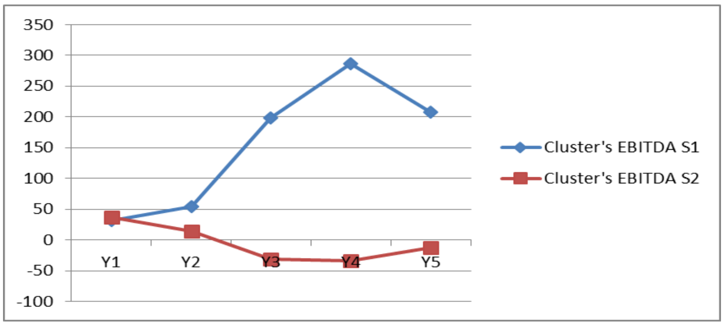


Fig. 59 EBITDA comparison: Sample 1 vs Sample 2

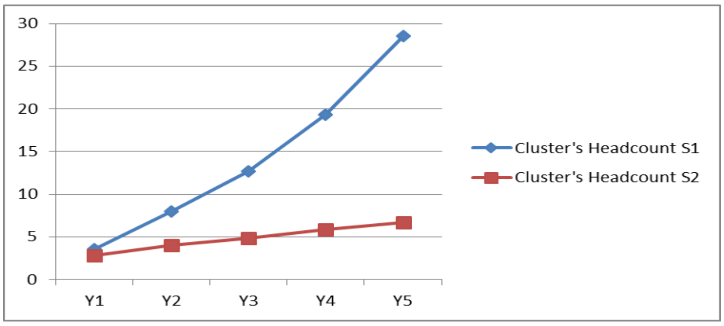


Fig. 60 Staff comparison: Sample 1 vs Sample 2

Thus, by using 2 samples of companies from the same cluster and originating from the same parent company, we obtain considerable differences in terms of both Turnover and EBITDA as well as headcount evolution. And yet all the companies are viewed as innovating and positioned in the same industrial ink jet technology.

Where do then the differences come from?

In fact, it turns out that the 2 samples are almost to one company the same!

The calculations were indeed made in the very same way by taking the first 5 years activity of the various companies considered in each sample.

The figures of the companies taken into account were recorded and processed for each one of the 5 years. This made it possible to obtain an average on an annual basis for the 3 performance criteria.

In the first comparison (fig 55-57), there was clearly a scale effect that was distorting perception.

It just seemed that the two samples were akin to each other.

When they are compared with a common reference, the 2 company samples from the same cluster appear to be very different instead.

In fact, choosing the parent company as the reference for the first comparison, is choosing the company that has the greatest impact among all the companies in the sample.

In addition, if big differences appear in the 2 samples for all 3 criteria, the 2 samples turn out to be nevertheless much closer to each other than one would have expected!

Indeed, the compositions of the 2 samples seems to be practically the same!

In fact, the composition of the 2 company samples is the same … with just one exception.

There is indeed just one company that belongs to one sample but not to the other.

The company included in the first sample but not in the second is clearly the parent company that was behind the cluster.

It therefore has a very strong impact on the overall result.

So we had:

SAMPLE 1 = Cluster's data with Parent

SAMPLE 2 = Cluster's data without Parent

3.1.3 One outlier impacting the overall results

Let's then zoom in on the performances of the one company belonging to the first sample and not to the second (showing parent company figures again).

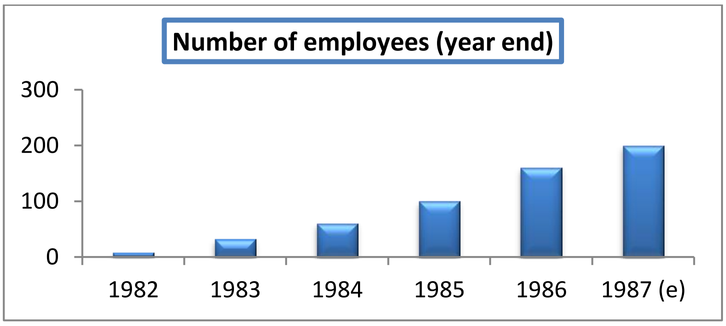


Fig. 61 Parent company headcount

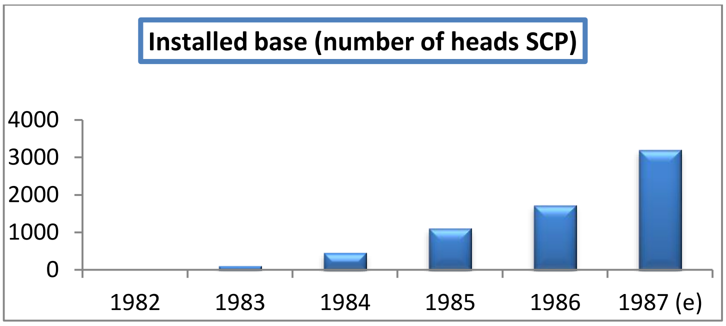


Fig. 62 Parent company sales

In this case, the performances, as we will demonstrate, are exceptional.
The importance of the exceptional clearly speaks for itself in the following graph.

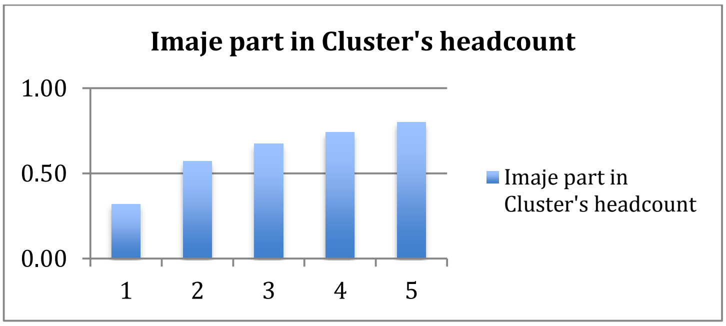


Fig. 63 Imaje's share in Cluster's headcount.

Just consider that number: Imaje's share in the cluster's headcount overpasses 80 % … And it's going up over time!

We have thus an example of « Superior Performance » (Porter, 1990) through a company combining strong market share and high value, thanks to an innovative technological solution.

So, we are no longer faced with « ordinary » differences between companies. The degree of difference shown suggests a specific identification for this unique performance level.

What we call Outstanding Performance (OP).

The OP is confirmed by detailing the results of the various companies in the cluster:

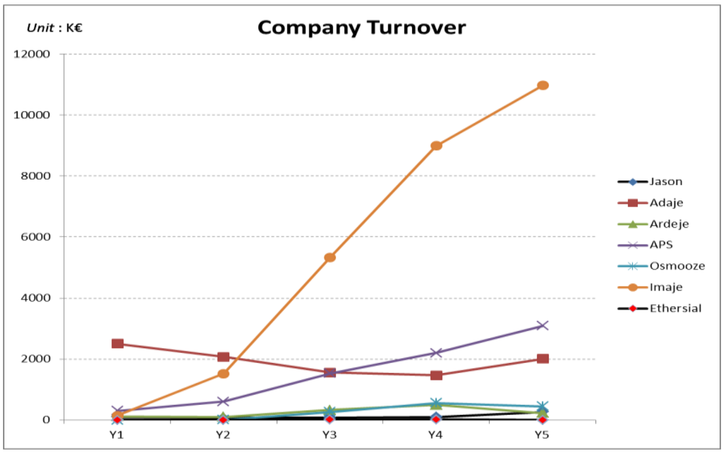


Fig. 64 Turnover Detailed Results (Cluster)

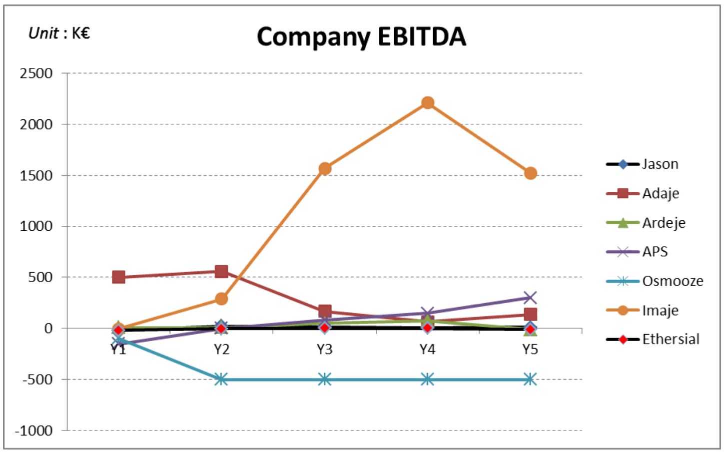


Fig. 65 EBITDA Detailed Results (Cluster)

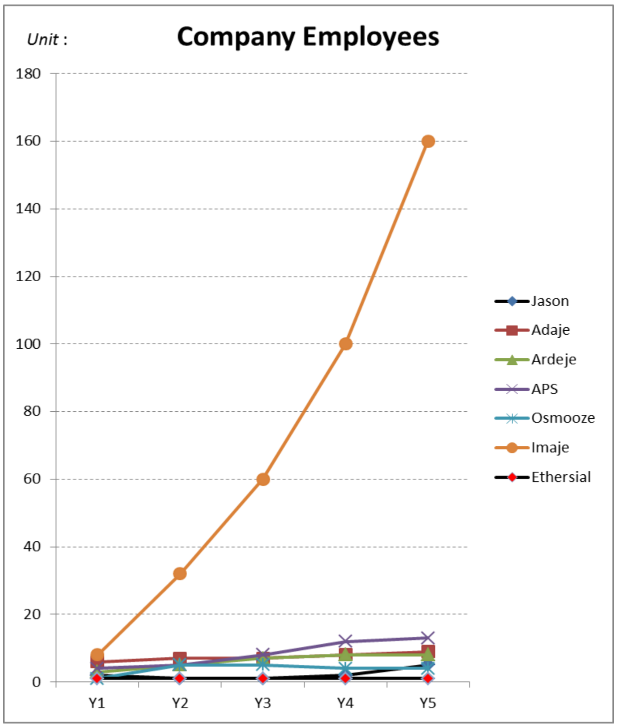


Fig. 66 Headcount Detailed Results (Cluster)

We therefore observe:

- The presence of an outlier on the 3 dimensions measured and across all the other companies in the cluster.
- The very strong impact of the exceptional on the average. Conversely, the average conceals the exceptional! (As we saw above).

Thus a sole outlier in the series leads to very different overall results.

Is exceptional performance linked to a higher level of disruption?

The evolutionary account of the spinoffs from the French ink jet cluster in the Rhone-Alps region reveals the following: Companies that, on the face of it, are quite similar can show very significant differences in their development rates right their first years of activity.

And yet these companies are positioned on the same technology, are in the same geographical area and originate from the same parent company.

In fact, by investigating the ink jet technological cluster, we have highlighted the presence of an outlier.
This means that beyond the usual classification of spinoff performances, we need to add an exceptional performance category.

This would add another rung to the performance classification scale that takes 3 levels into account: failure, marginal survival and high growth.

Indeed, the outlier considered has an impact through its results on the entire cluster that it belongs to and in a very significant way.

To the extent that its presence or not in the calculations makes the samples unrecognizable.

In our case the outlier turns out to be the parent company.

This led us to consider that the technologies developed by the spinoffs of this company could turn out to be less similar than they seemed at first sight. And this despite the fact that all the companies in the cluster, including the parent, base their development on the same generic technology represented by the industrial ink jet.

The highlighting of differences in the technological variants controlled by the cluster's industrial actors, including the parent company, is supporting this argument.

Nonetheless, more advanced investigations into technology layers used by the different companies will be needed to be able to reach a conclusion.

Indeed, it is easy to confuse technology layers, because these layers are very similar and hide underneath each other like Russian Dolls!

3.2 Disruption theory and outliers

We question the bond between disruption and performance in the fluid dynamics industrial sector. Performance of spinoffs from the same parent in high tech clusters.

We have previously shown:

1- There is performance in the 2 clusters surveyed.

Let's prove this performance.

To do this let's keep in mind the companies in the cluster and their increases in staffing levels and turnover.

Let's also use the average growth rate of the companies that are not just craft businesses, as well as the average failure rate of new companies.

Now we can compare:

Half of the new company creations had ceased to exist 5 years following their launch (Les Echos / Insee 2013).
This was already borne out by the 2006-2011 study from the same sources: From the 286 000 companies created in 2006, only 50% were still operating 5 years later

If we examine these results in detail, we can see (KPMG Survey, 2007) that:

- The increase in turnover (between 2001 and 2005) of the (surviving!) French SMEs was :

  + 17 % (and + 6% or more for the big companies / SBF 250).

- The increase in staffing levels during the same period and for the same sample shows: + 6% for the SMEs (and - 4 % for the big companies).

Such figures bear no relation to the average performances achieved by the 2 European clusters that were studied.

2- There are DIFFERENCES (though) in the performances of companies in the same cluster.

Proof: That is what we demonstrated in the previous chapter.

What is true when we compare the parent's company performance versus the spinoffs' performance is also true when we compare between spinoffs.

Disruption theory and conventional strategic analyses tools provide a satisfactory and explanatory pattern to explain the discrepancies in performances observed *on average*.

This framework is the corpus of the *preconditions* for performance in the contexts of technological innovation.

In addition, 2 additional elements are to be considered:

- **Some outliers are greatly distorting the means.**
- **Some concepts associated with means are far too general. Thus, the concept of Technology itself. If one refers to "technology companies" as a set, most of the time this set will gather very diverse entities. And this unseen heterogeneity could lead to confusing conclusions.**

So, in the same way as we dealt with performance, we will study and qualify disruption, having already established it conceptually.

3.2.1 Detailing and qualifying the disruption.

We will show that most of the companies in the 2 clusters studied present a disruption, either purely technological, or business model related.

To do this, we will apply the relative criteria of technological- or business model disruption.

The purpose is to validate the potential matching with the companies surveyed.

« Disruptive technologies bring to a market a very different value proposition that have been available previously. Generally, disruptive technologies underperform established products in mainstream markets.
But they have other features that a few fringe (and generally new) customers value." (Christensen, *Innovator's Dilemma*, introduction p. XV, 1997)
In fact, disruptive technologies bring on the market dramatically higher performances on *secondary or new customer selection criteria*. In so far as the offerings related to the dominant design had, on these same criteria, reached a maximum or revealed an impossibility.

Synthetic criteria to qualify a disruptive innovation (Christensen, 1997, ibid): Disruptive technology underperforms the dominant technology on dimensions that the mainstream market demands but with *steady improvements* meeting or exceeding these same demands.

All the companies in the 2 clusters surveyed correspond to this definition *(see below).*

Do some of them even correspond to an advanced vision of disruption, namely Business Model disruption (Christensen, 2009)?

It is what we have to check at this stage.

For this purpose, let consider the 3 families of Criteria explaining a Business Model disruption-type:

- A specific Revenue Mode (« Value Network »)
- A specific Structure of Costs
- A specific Positioning (updated solution)

The 2 following tables are giving a synthetic view of the sources and recognition of potential disruption in the French inkjet cluster and in the British cluster as well.

Company (French Cluster)	Technological Disruption (criteria for superior performance Price / Value)	Business Model Disruption (initial base of revenue)	Market recognition of the disruption
Imaje	Value (Output)	Devices	Yes
Adaje	Value (Output)	Devices	No
Jason	Price	Devices	Yes
Ardeje	Value (Output)	Devices	Yes
Osmooze	Value (patented algorithm)	Devices	No
APS	Price	Service	No
Ethersial	No	Service	No

Table 16 - French Cluster and disruption

Company (English Cluster)	Technological Disruption (criteria for superior performance Price / Value)	Business Model Disruption (initial base of revenue)	Market recognition of the disruption
Inca	Value (Output)	Devices	Yes
Xaar	Value (Accuracy)	Devices (heads)	Yes
Elmjet	Value (Output)	Devices	Yes
Linx	Value (Output)	Devices	No
Willett	Value (Output)	Devices	Yes
Xennia	Value (Accuracy and Quality)	Devices and Service	No
Inkski	Value (Output)	Devices	Yes
Domino	Value (Output)	Devices	Yes
Biodot	Value (Accuracy)	Devices	Yes

Table 17 - English cluster and disruption

In the 2 clusters surveyed, disruptive technologies apply for most of the companies.

But as far as the **business model** is concerned, we can wonder whether the disruption is real at this level. In fact most of the companies are industrial actors. They are manufacturing products. And as such they target and took benefit from technological innovation.
Their business model is then rather traditional for industrial companies selling products or products plus services.
And none of them, in both clusters, intended at origin to be disruptive at business model level.
Their advantage in the first place was not coming for their cost structure or their positioning contrarily to what happened, for example, in the air transportation industry for disruptive so-called low cost companies.
In this later case, companies like Ryanair or Easyjet have really taken a dominant position thanks to their business model.
The cost structure of Ryanair is thus something like 20 USD per passenger when the same calculation for Air-France / KLM gives 120 USD (2012)!

From Professor Rigas Doganis (CSC) and from the Airline Monitor (1999) we also know, for example, that a cost per seat comparison (gas, staff, maintenance costs amortization and plane) gives: 5.04 USD for Ryanair vs 12.85 for Air France.[4]

So going back to the issue of the nature of disruption, we have to explore our clusters again to check if the disruption happening there is well from Business Model-style or not.

Besides, we have to explain the necessary linkage between technology disruption and performance of startups.

3.2.2 Validate the bond disruption / performance

Alex Miller (Taxonomy of Technological Settings, 1988) shows that the link is not direct between technology and firm performance.
But when he refers to technology, he solely studies production types and production methods, namely small batch, mass consumption (assembly line) and continuous process.
On our side we stick to the fact that technological disruption leads to some performance.
We subscribe in this sense to the research tradition in innovation considering the company as the unit of analysis (Brown & Eisenhardt, 1998; Ancona & Caldwell, 1992).
This "business-oriented" tradition discusses how innovative inputs are transformed into efficient innovation outputs.
And we do not examine the conditions and context of innovation: A second tradition in the literature which is economics-oriented (Brown & Eisenhardt, 1995, 343; Dosi, 1988).

This said, the big question about innovation performance is still to measure it!
As C. Christensen (2012) put it: "We need of a Theory to offer to managers how to measure".
And E. Von Hippel (2012) is adding that Literature is insufficiently precise on where the trust (the innovation) is coming from. For we tend to measuring performance differences between SEAMINGLY similar enterprises!!!

So we adopted the following scheme to display the data:

Step 1: We will consider each company

Step 2: We will show the pattern of success, according to authors, when there is a disruption in favor of this company

Step 3: We will identify the pattern of success (if any) in the general instance of no disruption.

Step 4: We will prove that the case of any outstandingly successful company in the clusters refers to point (step) N° 2.

We also decided to use a common criterion to compare and measure the performance of firms.

3.2.2.1 *Performance indicators*

Considering the EBITDA evolution appeared to be an appropriate method.
Thus EBITDA is well the major reference to value a company according to the well-known **Argos index** (see cession-entreprise.com & Argos mid-market).
Thanks to this index, we have access to quantified data and figures about levels of margin on sales for SMES.
That will help us to bring to the foreground a quantified criterion for OP.

[4] Intra European Airlines

Argos in its permanent analysis of unlisted companies is stating: "the most profitable companies on the market" have an average EBITDA amounting to 16.3%.Whereas the average EBITDA for industrial companies interesting investors is around 11%.
We can then deduce that 11% is above the real average EBIDTA of industrial SMEs.
For, and as we mentioned above, 50% of new companies disappear within 5 years after their incorporation.
And also because the targeted companies by industrial groups for a potential takeover are definitely, on average, companies that present an "above average" attraction.

So we can consider that most surviving companies after 5 years correspond to companies showing an EBITDA between 0 and 11%!
We associate these companies to a type. This type is gathering all companies with some performance but without disruption. The absence of disruption is phrased "No Effect Pattern" (NEP).

What we write the following way: **0 < EBITDA NEP < 11%**

Besides, if disruptive companies lead to more performance, over 5 years the disruption effect on performance should emerge.
As a consequence, for these companies, we should get an EBITDA in the vicinity or superior to 16%, or at least in the range between 11 and 16%.
That is what we propose to check below.
We want to check this EFFECT PATTERN (Effect Pattern with disruption) among the companies belonging to the French European cluster.

Here it goes to evaluate if and when for companies within the cluster: **EBITDA > 11 %**

And if EBITDA > 11%, we do have the **Effect Pattern.**

In a second step, we will countercheck this observation on the English cluster to see if the result is identical (to the established Effect Pattern).
If we consider primarily the French cluster as a whole and apply the logic described above, we obtain an average peformance for the cluster of 12 % (average EBITDA for the companies in the cluster over the period)

Therefore, on average, for the **panel:** EBITDA > 11%

So the actual observation of the 7 companies belonging to the French cluster is showing that this group matches the Effect Pattern.

Companies in the clusters	→	**Effect Pattern**
Most of the companies (after 5 years)	→	**No EP**

Thus, by positioning the cluster on the scale of performance previously exposed, we get the following ranking (fig. 68).

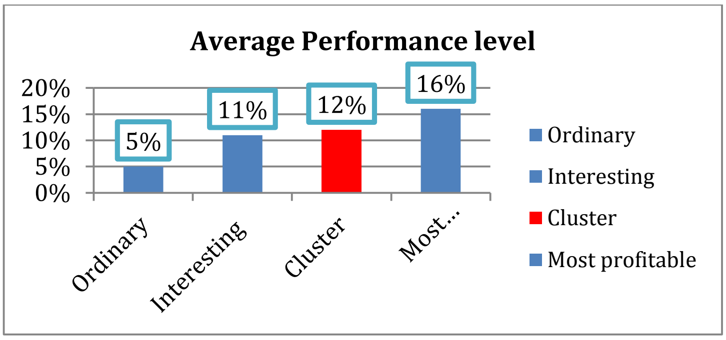


Fig. 67 Positioning of the cluster on a scale of performance

But not all the companies in the sample have achieved an EBITDA above 11 %: As shown below.

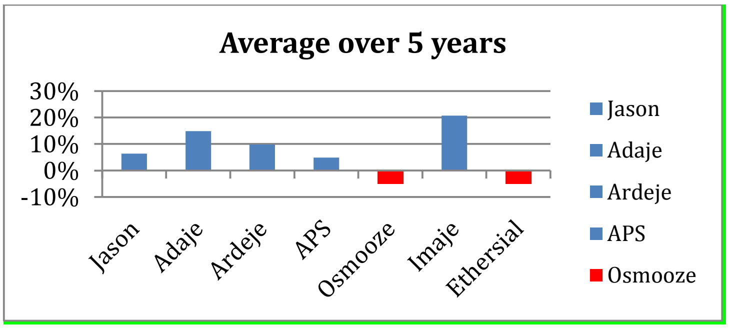


Fig. 68 « EBITDA / Turnover Performance »

So let us analyse just the companies in the sample with a positive cumulative result (EBITDA) for the period.

Company	EBITDA average	Best performance (Year)	Comments
Jason	6%	30,3% (Year 2)	Average performance to be put into perspective (see below)
Adaje	14,9%	27,1 % (Year 2)	
Ardeje	9,8%	15,5 % (Year 3)	
APS	4,9%	9,7% (Year 5)	Steady increase in the average over the 5 years and Year 5 = the best year
Imaje	20,7%	29,4% (Year 3)	

Table 18 - Companies' performance

NB: for the other companies in the panel (those that do not have a positive cumulative result for the period), we would tend to consider them as more than likely or even "due" to fail.

Clusters like these therefore confirm that disruption through technology encourages the growth of start-ups.

Indeed, even if it is true that not all the companies have an average EBITDA for the period higher than 11%, we find that:

- All manage to generate EBITDA figures well above 11%.
- More than half of them even manage to generate EBITDA figures well above 16% (the Effect Pattern threshold), and sometimes over 20 %!
- Moreover, in the case of Jason: only the impact of a negative operating surplus in its first year prevents the company from reaching the "11% threshold" . In fact, by excluding the first year of operation the calculation comes out at 10,9% (57 K€ / 521 K€).

We are well aware that the launch years, particularly the first one, often have an adverse effect on the result.

Therefore, not only are the panel results partially underestimated because they include the very first year of operation **(penalizing in 5 out of 7 cases, and even 100% of cases ...)**, but also because they **only** represent a period limited to the first 5 years.

- In the last case, that of APS, the analysis, though different, is in line as far as the conclusions are concerned. Indeed, even if neither the average performance (4,9%), nor the best performance (9,7%), support an Effect Pattern presence , a more detailed analysis could nonetheless reverse this interpretation . For, as we saw earlier, the potential disruption of the APS offer is based on a service and price value. Two elements that structure a business model disruption (see Table 18 above).

  But this type of disruption takes time in taking hold because it generates economies rather than gains. On the other hand it contributes to an outstanding recurrence. This is shown in the development of APS's performance over the 5 years (see diagram below). Moreover Year 6 for APS enabled the company to achieve an *EBITDA* ***of more than 15 %.*** Once again a better result than the previous year and during the period of very high performance (EP ~ 16%). The latter thus confirms the power of recurrence.

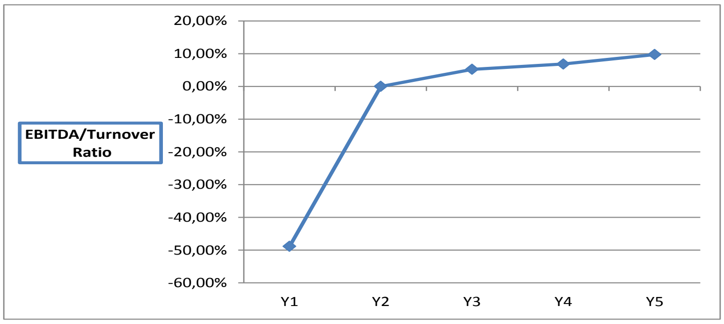


Fig. 69 Development of APS's performance (Curve)

So the performance ratio evolved from - 50% to + 9.7% between the first and the 5th year of activity.

The set of analyses above therefore validate the link between disruption and performance that we were putting forward as an assumption.

This we illustrate in the following way:

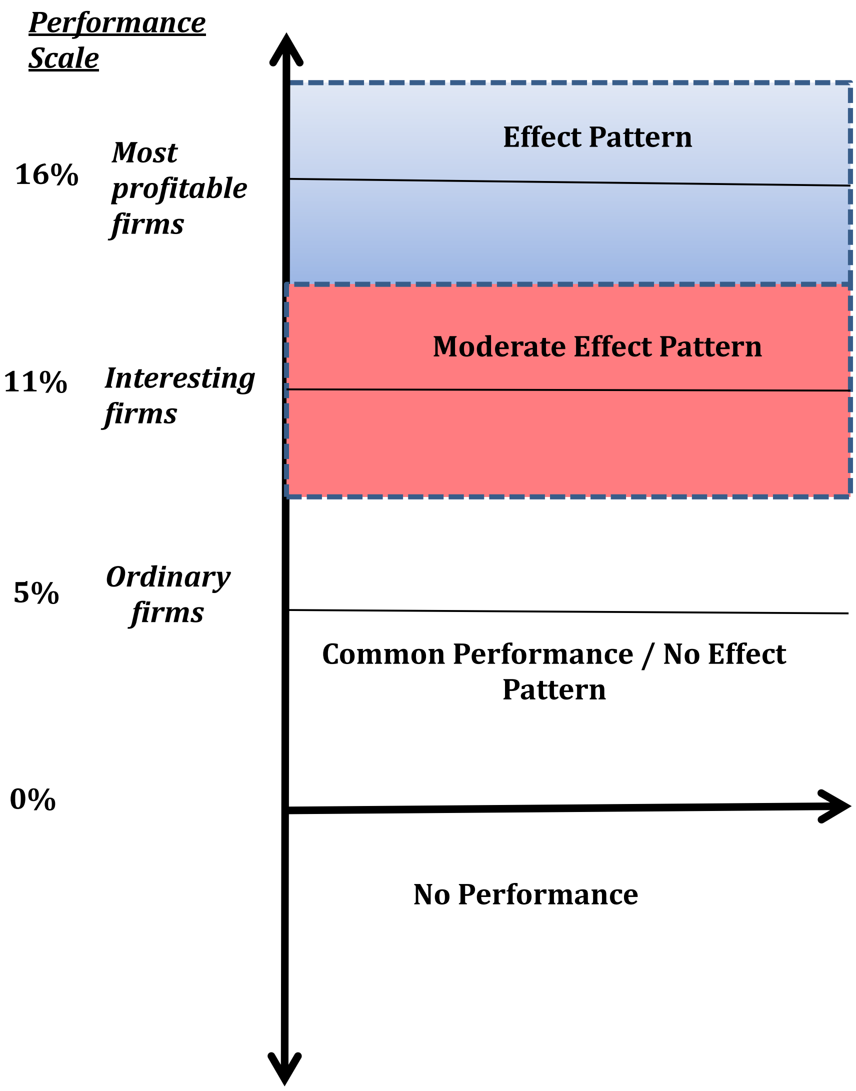


Fig. 70 Summary Table Disruption / Performance

3.2.2.2 *Applying the model*

Once defined, we used this model to rank companies within the cluster:

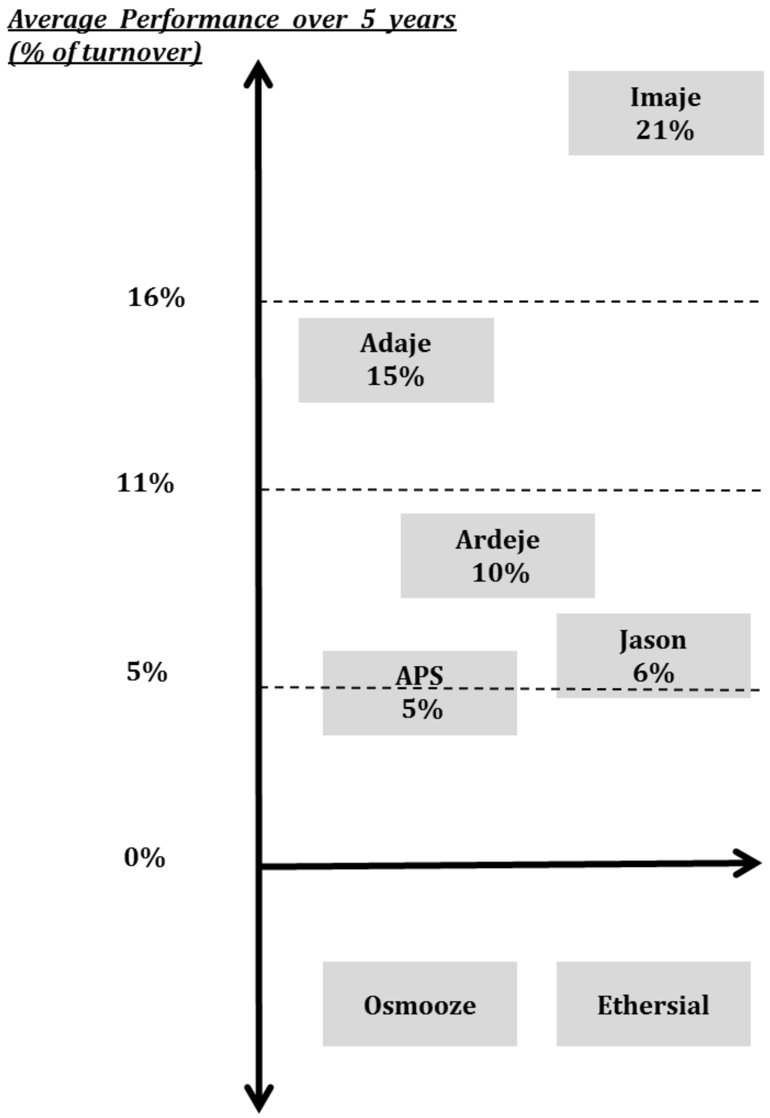


Fig. 71 Performance scale between firms

Of course, the "numbers" on the scale are mostly giving a reference as far as performance is concerned.

Intervals of confidence have to be considered around these values. In other words, there is certainly a margin of error to qualify each level of the scale.

There can be some variation on the limits beyond each of the nominal values.
If indeed there is disruption and performance, we nevertheless observe wide variations in performance between the companies in the clusters. There are some companies, in particular, that stand out from the others in terms of performance (see diagrams in previous chapters that compare cluster companies).
« Outstanding Performance » is traditionally associated with disruption.

But disruption, even though from a Business Model type does not seem enough to explain Outstanding Performance. A concept that we introduce based not only on a remarkable EBITDA level but also on an exceptional growth in the turnover and number of employees.

This (OP), moreover, is what we all have in mind when we are not specialists and when we're thinking about a (successful) startup.

Disruption does not seem enough to explain Outstanding Performance because we can see that for an equivalent level of technical disruption there are still considerable differences in performance between the companies.
What level of disruption should be chosen or established to support this statement?
We are not looking to prioritize in details. We simply consider as « evenly » disruptive the group of companies combining:

An innovative technology AND a satisfying new application.

3 groups stand out:

a. 1 group of Oustanding Performance that includes companies from the 2 clusters :
    - Imaje in the French cluster
    - Domino, Lynx and Willett in the English cluster
b. 1 group of actual but lower performance (already proven beforehand) : From Jason to Adaje and including Ardeje for the French cluster.

   These companies, in keeping with what has been said previously, present a form of « Incomplete Disruption ». A disruption that does not result in OP, as if the disruption was restricted by a kind of "brake". As if there was something missing in this type of disruption: hence our qualification as incomplete.
c. Quite « ordinary » companies like Ethersial or Osmooze. Ordinary to the extent that they post negative EBITDA figures.

We therefore conclude that the performance differences sometimes originate from an « Incomplete Disruption ». In other words, an *actual* technology disruption for an application of proven-value.
But an incomplete disruption nevertheless, because an element is missing for the disruption to result in hyper growth for a company. The reasons for this incompleteness need to be found. They could relate to problems with the usage:

- Either in the technical expectations: Lack of reliability in the technology. In the case of inkjet, difficulties for example in obtaining sufficient repeatability for the system to run smoothly.
- Or in the market expectations: degree of customer demand beyond the system's capabilities, e.g. insufficient adhesive level of the fluids (scratch resistance tests for example).

To be identified, Incomplete Disruption demands more often than not a detailed understanding of the technologies involved in the disruption process.

In the case of micro-fluidics and fluid-jetting, insufficient knowledge of the technologies involved and their basic or deep differences can lead to false conclusions about disruption. Not only can a mistake be made as to the degree of disruption (complete ←→ incomplete), but also in the evaluation of a disruption (absence ←→ presence):

Thus, some solutions are going to be incorrectly considered as disruptive while others, on the contrary, are going to be trivialized when they should be considered as disruptive compared with what is available.

What we illustrate as follows.

3.2.3 A solution wrongly qualified as disruptive

Yes, sometimes a solution can be wrongly qualified as disruptive; for example, seeing DOD as a « functionally improved » solution versus CIJ in the field of marking (Ford and al., 2010 p. 2) turns out to be inappropriate.

In fact, DOD has existed in the coding area since the early days of CIJ; as proved by the existence and presence of the US company Marsh in these applications since the 80ies (one of a number of companies like Markpoint or Swedot).

Marsh is therefore an active and visible company, the field of industrial property rights included. As evidence we would mention the patent filed by Larry Kniepkamp (Freeberg, IL) for Marsh in January 1987 (Application Number: 07/068420 / Publication Date: 04/04/1989 / Filing Date: 07/01/1987).
True, it was for Valve Jet.

As a matter of fact, to be more precise, it should be pointed out that DOD PIEZO, that appeared in the coding area in the 1990s, represented at the time a potential alternative to the CIJ. But that's another story. In fact, the companies Markpoint and Swedot (Sweden), or Marsh that we have already mentioned, though well positioned then in the DOD technology, were developing a technique other than DOD PIEZO. Namely the DOD VALVE JET that has only the principle of « one Nozzle / one Drop » in common with the DOD piezo.

But, even with these considerations, the DOD would not be able to be considered as a STEP FORWARD, and even less a disruption that would have upset the market balances in the short term

In fact, once again, due to the technical problems it conveys, DOD has not, for marking/coding applications in general, been a damaging replacement solution for pre-existing ink jet solutions (CIJ). We confine ourselves to the CIJ processes as dominant solutions (see table 19 below: advantages / drawbacks of the DOD piezo for marking / coding applications). The reasoning though would be the same in the case of DOD Valve jet (vis-à-vis the DOD piezo) for secondary and tertiary packaging applications

DOD piezo vs CIJ	Drawbacks	Advantages
Application : Coding / Marking	Print distance (head / substrate) Speed Adhesion capabilities Too expensive or very cheap/not long-lasting (e.g. Spectra vs Epson) If « water based » inks: majority of supports outside field of use	Cost per head Print width Multi-colors possible Print quality (drop size)

Table 19 - Evaluation of 2 competing technologies for coding applications

There has not therefore been any *progress* for marking applications through a hypothetical evolution of CIJ towards DOD.
Moreover, this error of perspective on an assumed evolution between 2 areas of technology is common to a number of conclusions that punctuate evolutionary history both as a discipline and as a theory.
Indeed these findings are also to be found in the strictly scientific area of Anthropology and Life Sciences (see Stephen Jay Gould ; The Full House, 1996).

As S.J. Gould pointed out (ibid, p. 63) with an anecdote on the assumed evolution of the horse: « *Evolution rarely proceeds by the transformation of a single population from one stage to the next. Such an evolutionary style, technically called* anagenesis*, would permit a ladder, a chain, or some similar metaphor of linearity to serve as a proper icon of change. Instead, evolution proceeds by an elaborate and complex series of branching events, or episodes of speciation (technically called* cladogenesis*, or branch-making). A trend is not a march along a path, but a complex series of transfers, or side steps, from one event of speciation to another".*

In a nutshell, by continually focusing on the movements of the main trend of a population while neglecting its diversity, we arrive at «backwards» or reverse interpretations.

This is what S. Gould illustrates in his story about the horse: Historically, the evolution of the horse is the first evolutionary sequence to have been reconstituted (and popularized by Thomas H. Huxley, in the 1870ies).

The classic version of this evolution brings out 3 major trends:

1- Change in the dentition (molars)

2- Reduction in the number of digits

3- Increase in size of the specimens.

In addition, these three trends are correlated.

Over the course of time the evolution of the horse has become the paragon of what is known as an evolutionary « trend ».
It's at this point that « life's little joke » comes in. In the context of horses, it is precisely because the evolutionary bush is finally reduced to a single twig through constant pruning that it is very easy to see in the horse of today (Equus) a sort of culmination in the evolutionary sequence!
Our bias in depicting trends as « entities moving somewhere » (ibid, p. 63) enables us to "bring forth our conceptual steamroller" to straighten out the tiny path from the surviving twig to the ancestral stock.

Beyond the metaphor, we discover these same observations in their application to the evolution of ink jet.

On this front, as in biology, there is no lack of findings regarding errors of judgment in the causes and logic of evolutionary processes.

E.g. A seemingly trivial solution that turns out to be disruptive: In symmetry to what we set out above: there was not really any considerable progress in the marking / coding field during the '90s linked to the power of the DOD technology.

Symmetrically, therefore, not seeing a form of disruption in the application to the coding of « office automation » technologies (DOD piezo in its different forms), is to ignore the fractal nature of the markets.

Indeed, on the marking / coding markets the application of the DOD technology (see company Jason) to just the porous packaging / moving slowly and on eggshells (!) represents a real disruption. .

A disruption yes, but on just a fraction of the "Big" market that is normally considered. A single segment that becomes even more autonomous and differentiated from the moment a specific technology is applied to it.

However, and even though none of the above reasons would emerge to qualify the disruption, it must be concluded that some companies (most companies as a whole), fail to achieve Outstanding Performance.

We have already updated a series of OP Conditions.
The ones linked to the degree of intervention in the technological and market arborescence, that we associated with a « fractal approach » (Peters E., 1996).
These conditions are twofold:

1- Relevance of the technological variant chosen: OP appears when the technological « layer » is relevant (and especially not too general). This is what we examined and demonstrated by first differentiating CIJ (piezo) and DOD piezo, among the numerous types of ink jet and their variations in microfluidics.

Condition 1 is therefore to have a clear and detailed view of the technology.

2- Relevance of the selected technology/application pairing: OP appears when one considers a specific technology / application pairing on this new basis.

We tackle the 2nd condition: *Specify the application and the appropriate technological variant.*

An application will be defined by one or more performance criteria. These criteria can be formalized by using a Kano (Kano et al. 1984) model.

It's therefore a question, for example, of going from the analysis of marking using ink jet to « the analysis of marking primary or secondary packaging using CIJ »!

This « classic » approach in terms of strategic co-alignment (N. Capon, R. Glazer, JOM, 1987) well illustrates the cases of technological disruption when *The* chosen (sub) tech is a perfect match for an application.

But it is not enough: techno/application alone fails to explain Outstanding Performance. As we will state it in a new chapter.

Be that as it may, the questions surrounding the origin of OP outline a concept that enables us to add to the construction of the disruption theory.
We also see it as completing the idea of a Disruptive Business Model giving rise to new leaders.
Indeed, even if there is BM disruption in the final group of 5 (OP) companies in depth surveyed in the French cluster,, the BM disruption alone is not enough to explain the OP.

What appears to result in OP is a specific way of capturing value linked to the BM disruption.
In keeping with our approach, we will aim at showing where OP comes from by using a detailed study of the technology.
We see OP as being not just a Business Model sustainable disruption, based on the capture of value; but as a Business Model disruption « *plus* », that we describe as Complete Disruption.

At this stage of the dissertation, we can restate more clearly the research topic progress and our findings through a kind of matrix:

Evolution in Revenue Stream*	Changed	Increased	Boosted
Disruption Type	Technological Disruption	Business Model Disruption	OP Complete Disruption

** As compared to the disrupted solution (Value Network)*

Table 20 - Disruption taxonomy

In a way, the colored box in the matrix above enables the research finding to emerge from previously existing concepts used for the present work.
We are indeed isolating from the various forms of disruption, what we call Outstanding Performance.
For, in the case of Outstanding Performance, business model disruption is completed by another factor than the usual Cost Structure - Model of Revenue - Values framework.

This chapter is organized around the identification and the specification of this new factor of disruption.

Besides, we are converting knowledge from tacit to explicit in the sense that when the man in the street is thinking about innovation, his mind tacitly considers an exceptional success, exceptional growth, and exceptional performances. But one also knows how scarcely this happens.
Understanding OP is thus making the specific conditions for OP appear. It is trying to explain this kind of "King Kong Effect" on the key parameters of a company.

Chapter 4 - OUTLIERS AND OUTSTANDING PERFORMANCE: KING KONG EFFECT[13]

Where do the differences between some growth and hyper growth come from?

What makes for Complete Disruption?

At this stage the question is not so much about knowing whether a technological company has, or not, a radically innovative solution.

It's more about discovering what enables a number of them to achieve exceptional performances in terms of EBITDA, turnover and employment.

What dynamics underpin the Outstanding Performance of spinoffs?

An understanding of these dynamics should enable us to define our concept of Complete Disruption in a much clearer way

To do this, we first need to go once again into a detailed understanding of the technology and the applications.
To explain what we mean, when we talk about needing a detailed understanding of the technology and applications, we can suggest a 5 point scale of the understanding required:

- Lack of awareness
- Basic level of awareness
- Ordinary understanding
- Profound understanding
- Expertise.

In the case of microfluidics and ink jet, the 5 stages presented above can be expressed as follows:

- Lack of awareness: No comment.
- Basic level of awareness: Ability to visualize a microfluidic technology known as ink jet but without the ability to describe it other than a digital printing technique.
- Ordinary understanding : Ability to identify the 2 main areas of ink jet application that are :
    - Office automation on the one hand
    - And the industrial sector on the other.

  Without, however clearly understanding the specific constraints of the 2 technologies.
- Profound understanding:

  At this level of understanding it's about being fully conversant with the issues linked to the three fundamental elements of microfluidic applications: Printing Engine / Fluid / Substrate
- Expertise

  At this level, beyond being fully conversant with the issues and consequences of the above triptych, expertise covers:

A complete vision (as comprehensive as possible …) of the different branches of the technology.

A understanding and an interest in the emerging application fields (like the conductive fluids or the 3D applications at the beginning of the 21st century for example).

An awareness of the spectrum covered by this historical and technological knowledge at an international level.

The experts involved in the framework of our present study concur with this definition by level.
A definition that is a reminder of Pascal's 3 levels of knowledge approach (Les Pensées 1897, by L. Brunschvicg):

- "Ignorant" (on a subject): They know who they are!
- "Skilled": who today we would call experts and who merit the term.
- "Semi-Skilled": who think they are Skilled but who in reality are just « Ignorant ».

To come back to the core topic in this chapter: What dynamics underpin the King Kong Effect (Outstanding Performance)?
It turns out that on subjects as complex as microfluidics and performance, numerous comments and most academic papers clearly demonstrate real knowledge of the mechanisms involved. However authors may also underestimate some lack of knowledge which in turn prevents them from concluding effectively.

Sometimes, there are papers, particularly those covering subjects in the context of microfluidic technologies that give one the feeling that those who work on them are « semi-skilled ».
Ordinarily in these papers, people are questioning the potential insufficient knowledge / understanding of the triptych:

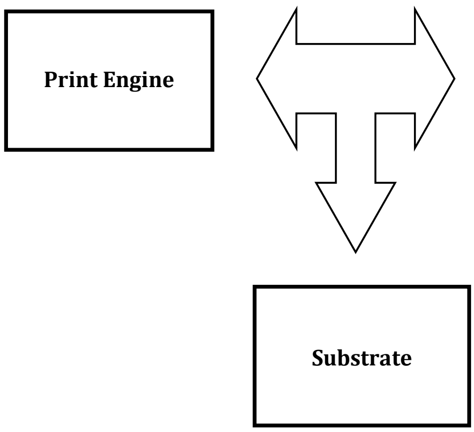


Fig. 72 The 3 major dimensions for research in fluid jetting

It is true that "from the outside" nothing looks more like an ink jet technology that another inkjet technology!

And without considering the *environment* of the ink jet system and its specific constraints (dust, humidity ...); what would still complicate a process en bloc, versus an exhaustive, detailed, comprehensive approach.

In this sense, we agree with Eric von Hippel when he suggests that the literature is insufficiently precise on where the trust (the innovation) is coming from. And part of our work is building on his own writings about: Measuring performance differences "between SEAMINGLY similar enterprises"!!!

In the present document, the findings at this level are issued from the building of the case study on the French ink jet cluster (Part 3.3)
But we do very well know that further inquiry could explore other companies, other sectors, other fields of knowledge like B2C environments. The results would build up upon the theory of disruption enabling to still precise the conditions of hyper growth.
At present, "Unicorns", these start-up companies valued at over USD 1 billion, are very fashionable.
They not only represent a financial amount but also contemporary desire, dreams and a vision of something exceptional. Just like the unicorn mythological animal!
Amazon is part of these extraordinary ventures. As can be seen below, even among very successful companies, Amazon appears as an outlier.

So the application to such cases of the analysis framework proposed in the present work would constitute an interesting additional contribution.
That leaves room to new research and inquiries to deepen the reasons and meaning of outstanding performance.
The question around companies' performance would probably soon connect with other issues on the efficiency of alternative business models.

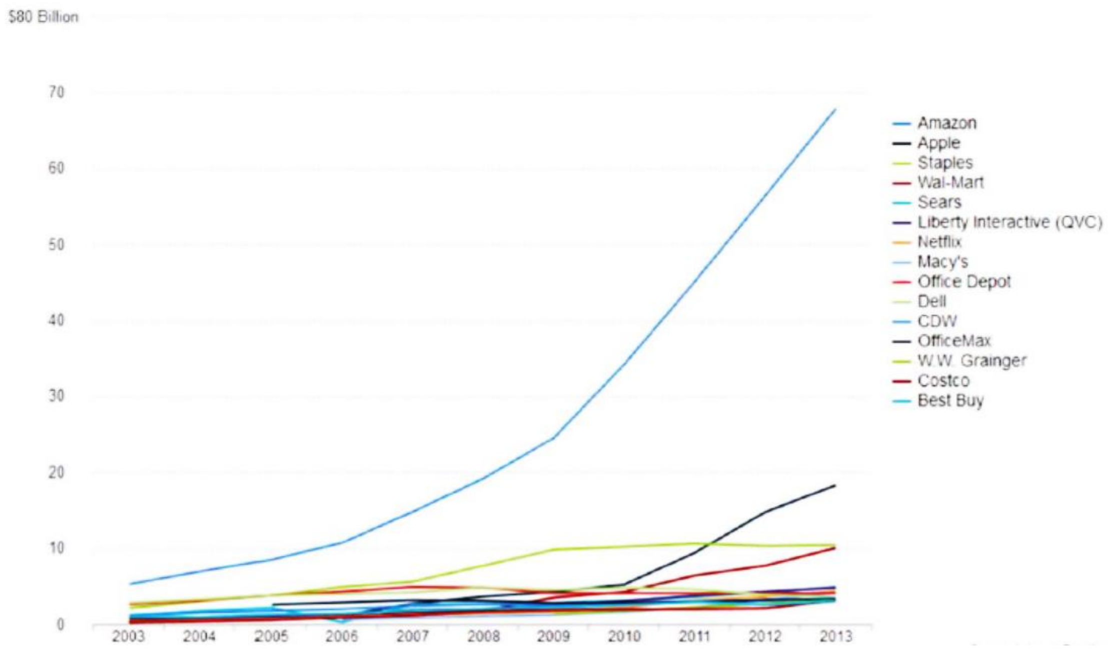


Fig. 73 An outlier: Amazon outstanding performance in turnover (source: internet Retailer 2014)

In short, and to come back to outliers in inkjet clusters, we first pointed out that we were not interested in qualifying *the intensity* of the disruption but rather in defining the *characteristics* of the disruption both from a technological as well a Business Model point of view.

We were then interested in defining the characteristics of specific disruptions. The very same disruptions that would form a startup with exceptional performances from a radically innovative company.
This enabled us to define what we call Complete Disruption, which we associate with Outstanding Performance (see: Table 29 further).

4.1 Tails and belly in statistics

We have to find Complete Disruption and its consequences on Outstanding Performance in areas of knowledge that are usually neglected, and probably far from being fashionable.
It seems, indeed, that as far as management of technology is concerned, most findings are focusing on management and underestimating the place of technology: organizational theories, learning theories, agency theory... All these theories are mainly management driven.
But the findings in the innovation field can be strongly impacted by tiny technical facts and physical realities: In the case of ink jet (CIJ), a very slight lack of accuracy in the algorithm related to the power tension to be applied to the jet can make a serious gap in terms of performance!
This very specific technical point made in fact the difference at origin between the team in Cambridge and the team in Valence. To such an extent that the Valence team lately subcontracted to the team in Cambridge a survey on this same topic!
We are far in this sense to price advantage, to segmentation scheme or entrepreneurial capabilities, far from pure management matters in a word. But we are at the heart of innovation on the side of technology.

We thus recommend not to forget or to underestimate the key role and place of technology in the dynamics of firms, specifically in the case of high-tech spinoffs and startups. Not in general, but through kind of hidden drivers of performance in specific technical choices and developments.

Another point tackling with hidden drivers of performance in high tech companies relates to outliers and statistics. Generally speaking outliers are just not considered in a statistical series.

What can people do with exception and chance?
Probably not a book, perhaps even not an academic paper.

So we analyze the common and we progressively tend to underestimate the value and even the real probability of occurrence of uncommon events. We unconsciously integrate these habits as part of a consistent scientific approach and rules.

Two more epistemological biases are then appearing:

1- When it is rare, it is underestimated. Does it mean that one does not consider the occurrence of very improbable events?

   This is not certain. But something is certain: The probability of occurrence is underestimated! (Nate Silver, p.424; see also Daniel Kahneman’s “availability heuristic”).

2- We stick to the more 80% of significant data. Thus, we are mixing Gauss and Paretto in a strange (fake) golden rule.

But to make outliers clearly visible, we have to switch from a system close to the statistical « bell curve » (from the Gaussian or Normal distribution family) into one that is *highly unpredictable* (because of the probability of occurrence of exceptional events).
The latter moves mostly by jumps, called “fat tails”: A system in which supposed remote events, those in what is called the “tails”, play a disproportionate role. And, in this case predictability is very low.

We all know the turkey problem: Near Christmas turkeys feel incredibly comfortable! It reflects the problem of “increased statistical confidence” (Taleb, Antifragile, p.93).

4.2 Outstanding performance and asymmetry

Staying in statistics, but looking at something else than the Gaussian curve, we have to analyze the statistical "status" of Outstanding Performance.

We know that the dream of any Business School student willing to start a new venture is to give birth to another Apple, Microsoft or Google.

But we are also aware of the failure rate affecting startups.
Does this mean that there is a kind of symmetry between success and failure?
Or, conversely, is there an asymmetry and in what sense? Positive (i.e. "convex") and bringing potentially more value than losses. Or negative (i.e. "concave") and the risk would be in favour of more downsides than upsides.

According to the scholar answer, you can expect to get more "Gain than Pain".
There is a theoretical "convexity" (Taleb, 2012, p. 273) embedded in a new venture project: In case of success, the potential gain is indeed superior to the potential losses.
For the losses (unsuccessful venture) are limited. They cannot exceed bankruptcy!

While the potential gains are theoretically infinite.

This is, if need be, a clear momentum in favour of creating new ventures!

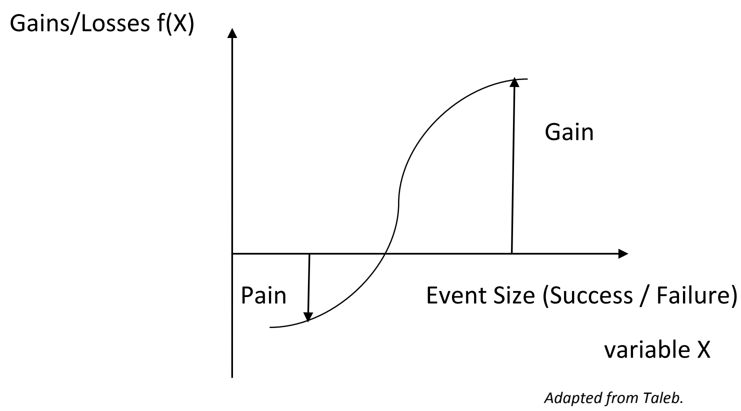


Fig. 74 Example of "convexity" in statistics (adapted from N. N. Taleb).

The graph illustrates a positive asymmetry. For a set deviation in the variable, in equivalent amounts in both directions, the "convex" brings more gains than losses.

To continue on the theme of chance and statistics, let us remember that Outstanding Performance is rare; so rare that we can associate it to remote points on the tail of a bell curve.

So rare that we can also associate it – still using the same wording around the conceptual framework of *randomness* - a (positive) "Black Swan Event".

This suggests some nonlinearity in the relationship between the intensity of the disruption and the "Performance" of a specific company.

Then we would have the following correlation: the more intense the disruption, the more convex the exposure.

In other words, the higher the disruption intensity, the more outstanding the performance, and disproportionately so.

For,

1- **The various types of disruption (see Table 29 on disruption models) are not to be considered as "boxes", but as continuums connected to each other and covering an infinite series of levels in intensity.**
2- **Very large deviations in a convex curve lead to disproportionately larger and larger effects. What we illustrate in the following figure (see also endnotes):[14]**

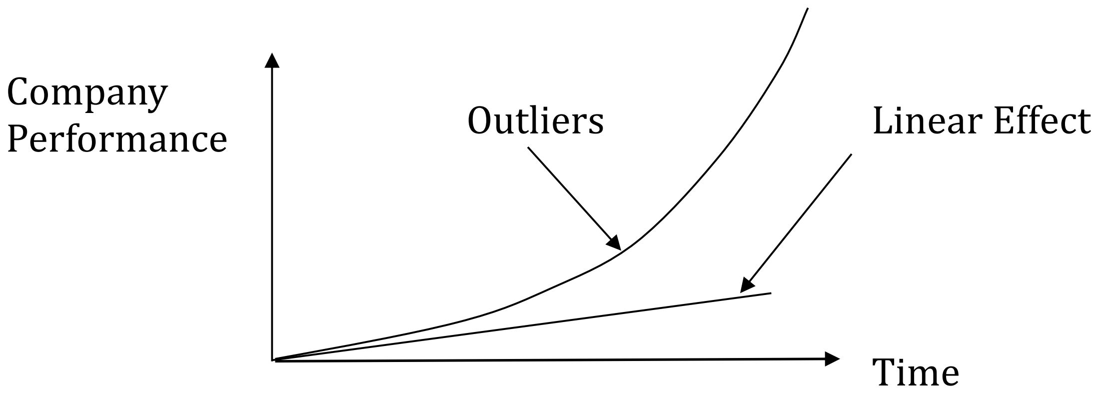


Fig. 75 Linear and "Positive Convexity" effect.

There should be further research to establish more accurately the shape of the relation between linear effect and Outstanding Performance: Is it a continuum? Is it a curve? What are the potential thresholds and discontinuities?

But let us go back to the positive convexity that we mentioned above and that we considered as a positive momentum for the creation of spinoffs and new ventures as a whole.

As we put it, it is theoretical.

For, in reality, we could, conversely -to what we stated before-, consider that an entrepreneur is exposed to a "negative asymmetry".

Indeed, he can lose everything: all the money for sure. But also, more money than the single money initially invested, plus self-esteem, plus friends, plus numerous other invaluable things in life.

And in fact, the entrepreneur, according to constant statistics, is failing most of the time. So the odds are against him.

On the other side, and in a minority of cases, he can expect a gain. But the potential gain, if we exclude outliers (Outstanding Performance), is very limited.

So we are facing "concavity" (i.e. negative convexity effects): The Entrepreneur can expect just More Pain than Gain!

The next figure shows a curve based on such a negative convexity effect.

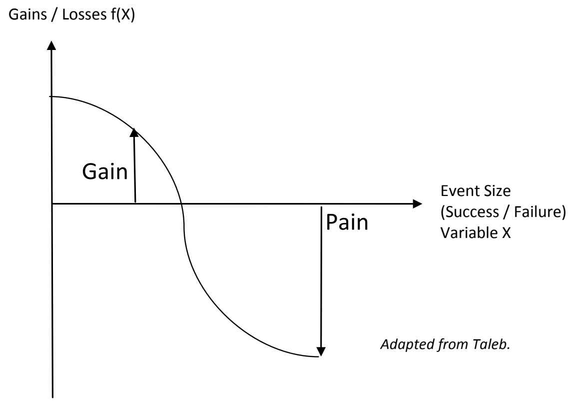


Fig. 76 Example of "concavity" in statistics (adapted from N. N. Taleb)

And as we know the generic bell curve and its properties … This curve is not appropriate to what we develop.

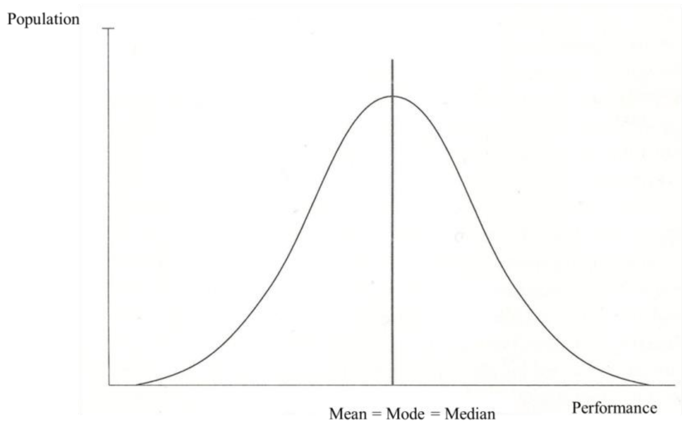


Fig. 77 Reference bell curve.

Indeed, when considering performance of new companies, the reference curve is not perfectly balanced in two parts.

This one is based on a constitutive asymmetry accounting for an imbalance between the chances for a firm to perform moderately and the chances for this same startup to hyper perform.

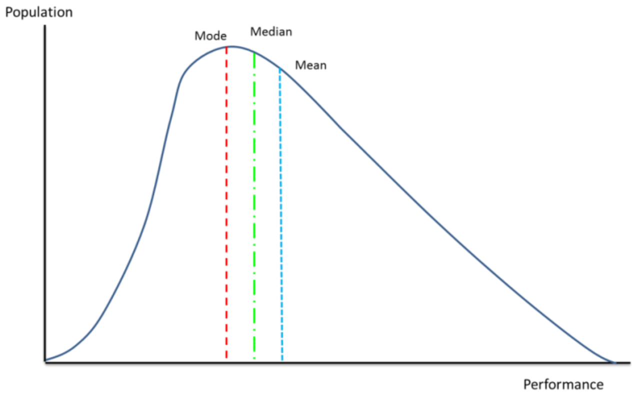


Fig. 78 Left skewed curve corresponding to the French cluster

Such curves are considered and named as “skewed", for they are in a way unbalanced and asymmetric. The fact that they are skewed translates in different values for their mode, median and mean.

The conclusion leads to consider that we are then in a typical case suggesting a “Barbell Strategy”: The average position (launching a company that will moderately perform) is not good, because the risk of failure will be higher and higher over time.

So before starting a company the choice is twofold:

- Either playing safe and avoiding to start any venture!
- Or targeting an exceptional performance, the only scenario enabling to “compensate” the intrinsic risk.

But to target an exceptional performance, one needs to understand the origin of such a hyper result.

So we are still left with the question: ***Why*** do some companies only, manage to reach an exceptional / outstanding performance (OP)?

4.2.1 The Origin of outliers

To go further in the understanding of OP, let in the first place consider: **What OP is not!**

1. Outstanding Performance is not a question of market.

   Proof: We will demonstrate this clearly in the following paragraphs by comparing laser and inkjet.

2. Outstanding Performance is not a question of technology (in the usual sense of the term).

   Proof: Again, we will demonstrate this clearly in the following paragraphs by showing that not all ink jet companies have exceptional performances – far from it.

   A subject that has already been covered in this work when we compared the performances of the various companies in the clusters (see, in particular, the section: In Search for Outstanding Performance).

Let us now come back to the laser/ink jet difference to illustrate the King Kong effect associated with Outstanding Performance.

The sources used for the whole next section were as follows:

- Survey (October, 1995) on cost comparison.
- U.S. trade show report (1999).
- Evidence run by the experts.
- Copies of Packaging Week magazine (1995).
- CLinvest Corp. Memorandum (1995) on the sate-of-the-art in microfluidics technologies.
- Executives, technical managers and product managers from ink jet manufacturers.

4.2.1.1 *Laser vs ink jet*

- Advantages (Laser)

  - Very low running cost (no inks)
  - Permanent mark

- Disadvantages (Laser)

  - High capital cost (4X more than ink jet for the device)
  - Lower speed
  - Permanent mark
  - Head has to be close to cabinet (for most sub-tech)
  - Limited range of substrates
  - Bulky and inflexible cabinet
  - Versatility? (if not Beam technology)

- Prices and Value Capture

  - The average price of a **Laser printer** (CO^2) amounted in the middle of the 90ies (heydays of disruptive digital coding systems) to roughly: ***35 K€+*** (around 250 KFF).
  - For an **Ink Jet** (CIJ) device it was: *11 - **12 K€*** (< 80 KFF)

  These prices are to be considered machine **installation** included. And they refer to multiple sources: Interviews with Experts, CLinvest Report and secondary data including an internal document from Imaje S.A. dated 9/4/1995).

Considering all the differences above, and the ones mentioned in Table 7, what were the reasons for the limited success of laser and the reasons for the great success of CIJ?

It is a question of value capture intensity: With ink jet, when you start generating revenues from ink sales, you are boosting the value capture and you are able to generate the funds to reinvest in various development initiatives (subsidiaries and network, R&D, advertising …).

This is consistent with the literature on new ventures and innovation ecosystems.

Basically we know that the position in the structure of value creation within an ecosystem affects value capture (Wasserman and Faust 1994). We are also aware that business ecosystems - like clusters - are places of *distributed innovation.*
But even if articles on "Momentum of Ecosystems" (Suresh Kotha, 2012), or "Lean Entrepreneurship" (Ries, *Lean Startups*, 2011) have flourished, it is nevertheless true that there is little focus on small companies for ecosystems.
This justifies by itself our interest in digging the reasons for different performances between new companies arising in the same technological cluster.

So much so that the "Dual roles for ecosystem Entrepreneurs" (Satish Nambisan, 2012) were represented in the clusters surveyed: Ecosystem Followers as well as Independent Company Leaders (Flagship companies).

Considering these frameworks, we showed that OP appears when one is **measuring** in concrete terms (i.e. through figures! and not only conceptually) **levels of value capture**.

In the case of CIJ ink jet, exceptional standards of recurrence manifest.

Proof : We will bring the proof of it by comparing the margin generated by one device in the case of exceptional recurrence (CIJ) to the margin generated by one device using another competitive technology (laser).

Further to our dissertation we will highlight the role of an explosive recurrence boosting the disruption!

If in section 3, we have established the bond between disruption and effect pattern, we want in this paragraph to show the effects on the profitability (hence on EBITDA), of an exceptional Re-Buy.

I***n order to achieve this, we will measure the comparative developments of Laser CO^2 vs CIJ Inkjet in terms of Additional Margin.***

This Additional Margin will come from the cumulative gross margin generated after 1 sale, after 2 sales, ….. (x1, x2, x3 ….).

We are assuming, and we want to show in a demonstrative way, that the generation of resources is leading to a growth rate **acceleration** (through the reinvestment of the additional resources generated that, in turn, generate more resources themselves, and so on, so forth). Thus:

→ The x+1 sale comes faster!! (coverage…),

→ And we observe a ***« convexity effect » (cf Taleb). Convexity as detailed above.***

We would get, if the hypothesis is confirmed, the following type of curve:

Reference scheme:

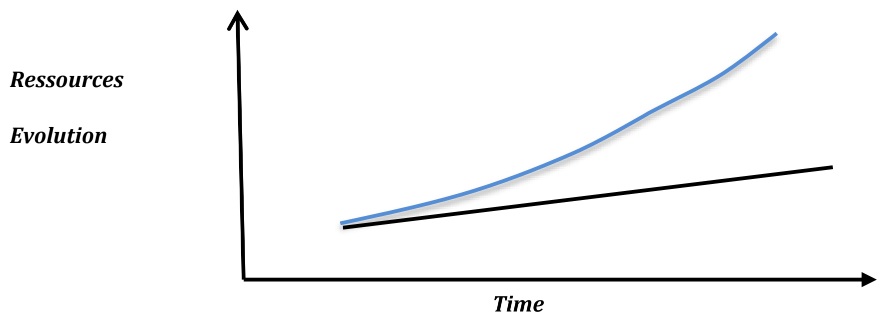


Fig. 79 linear and nonlinear evolution hypothesis.

The nonlinear curve would represent the recurrence mode associated with CIJ margins over time.

Future research on the topic could lead to taxonomy of recurrence modes (how many families?) as a function of the generated margin.

4.2.1.2 *Laser vs inkjet: Methodology*

We describe the methodology used to build compared graphics based on CIJ inkjet technology and CO^2 laser.

To create the comparison curves, we propose equating the comparative costs and revenues for ink jet and laser, by not only considering the generic technology but also the specific technologies of the CO2 laser and the CIJ (for ink jet). In other words the 2 types of technologies the most widely used for the marking / coding applications that interest us.

Reminder: The following calculations are established by using the basis of prices recorded at the beginning of the 90's – early maturity period of the CIJ market.

Additional ink jet CIJ / laser CO^2 comparative data:

1- The recurrence is weaker with the laser; each piece of equipment installed generating less induced turnover than with ink jet (see table with summary and entry data).

2- But IN ADDITION: The recurrence linked to the laser relies mainly on the occasional but essential renewal of the *sources*. In other words mechanical elements that generate an average industrial margin typically around 50% (gross margin).

   Whereas in the case of SCP ink jet, the consumables (ink and solvent) give rise to very high «profitability» to the extent that the margin (gross margin) on the fluids can be 50% higher than the margin on the printers.

   With the production costs also being reduced by comparison, the result is an exceptional source of recurring profit (operating margin), higher than 30 %!

   As a consequence, *right from the first year* of operation, an SCP printer generates as much profit through its recurrence of consumables as through the sale of the equipment itself.

   We will demonstrate this through the calculation and in an illustrated way.

We therefore propose comparing the two models of resources linked to the two technologies considered:

1- We precise the variables that we are considering
   - A = purchasing price of the equipment (installation included)
   - F = Annual cost for the fluids / gas (CO^2 cartridges)
   - M = Maintenance Yearly cost
   - S = Laser source replacement (every 3 or 4 years)
   - Cn = Total cost for year « n » of the equipment
   - Tn = Total cost of ownership from year 1 to year n (Tn = C1 + C2 + C3 + …. + Cn)

We are thus looking for the value of Cn and Tn.

a- Inkjet Pattern (ink jet CIJ)

C1 = A + F

For n ≥ 2

C2 = F + M

C3 = F + M

…..

Cn = F + M

Hence, the following recurrence formula:

First result: $$Tn = A + nF + (n\text{-}1)\, M$$

What leads to – when we gather the « n » terms - the following final equation, in the case of CIJ inkjet:

$$Tn = A - M + n\,(F + M)$$

Equation 5 – Formula to evaluate CIJ inkjet recurrence power

b- Laser Pattern (costs to be taken into account for a user of a CO^2 laser)

Additional Variable: S

S stands for the replacement cost of the laser source.

What, over the years, leads to:

C1 = A

C2 = M1 + F' (Maintenance + CO^2 « refill »)

C3 = M2 + F'

C4 = M3 + F'

C5 = S Source replacement

C6 = M1 + F'

C7 = M2 + F'

….

Again, we see appearing a kind of recurrence.
It happens on a 5 years basis. So we get the total cost after 5n years:

$$T5n = A + [3\,(M{+}F') + S]\; n$$

Equation 6 – Recurrence formula for CO^2Laser

Hence, we will illustrate the resulting calculations for the 2 technologies considered in the present section with reference to the various price tables exposed.

4.2.1.3 *1st series of curves*

All the figures below are to be considered for one single device of each technology.

4.2.1.3.1 Laser vs inkjet comparison: Turnover

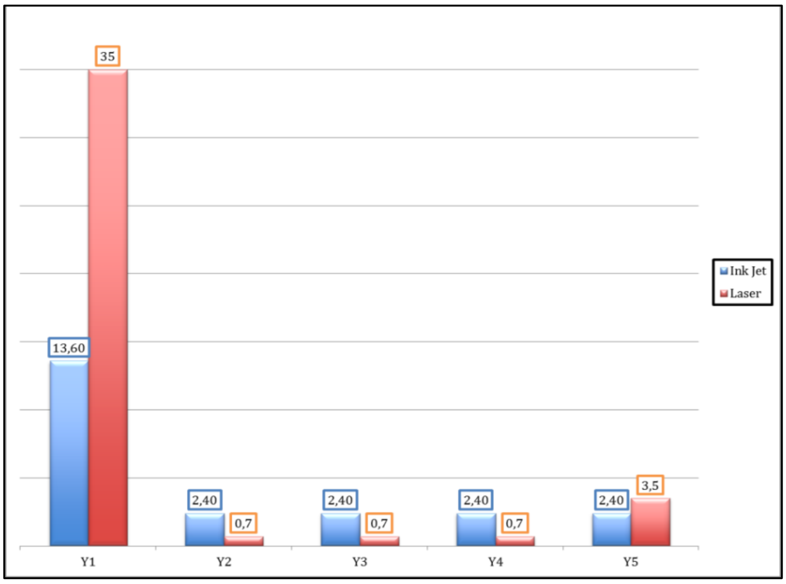


Fig. 82 SCP inkjet vs CO^2 laser: Turnover comparison.

4.2.1.3.2 laser vs inkjet comparison: Gross margin

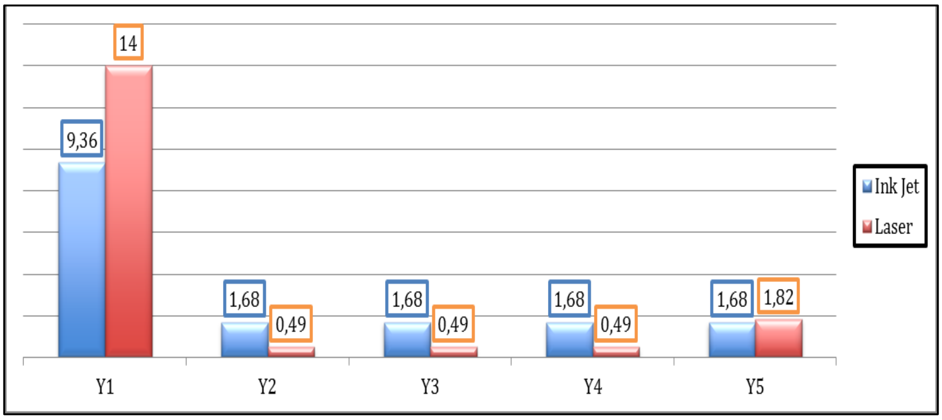


Fig. 80 SCP inkjet vs CO^2 laser: Gross margin comparison.

4.2.1.3.3 Laser vs inkjet comparison: Net Margin

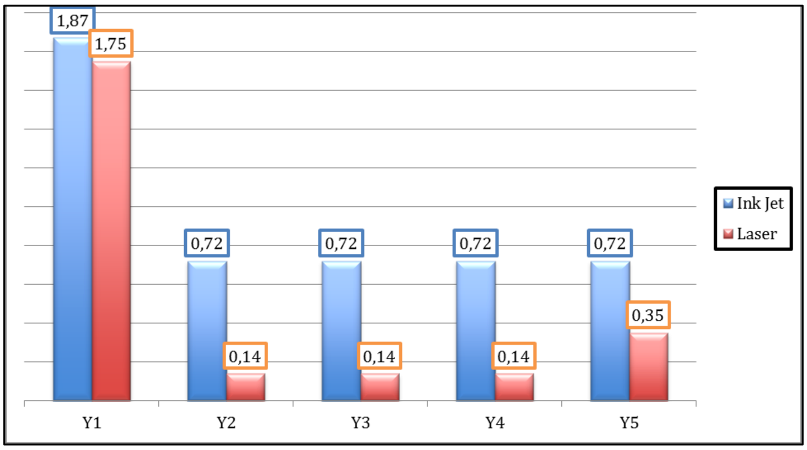


Fig. 81 SCP inkjet vs CO^2 laser: Net margin comparison.

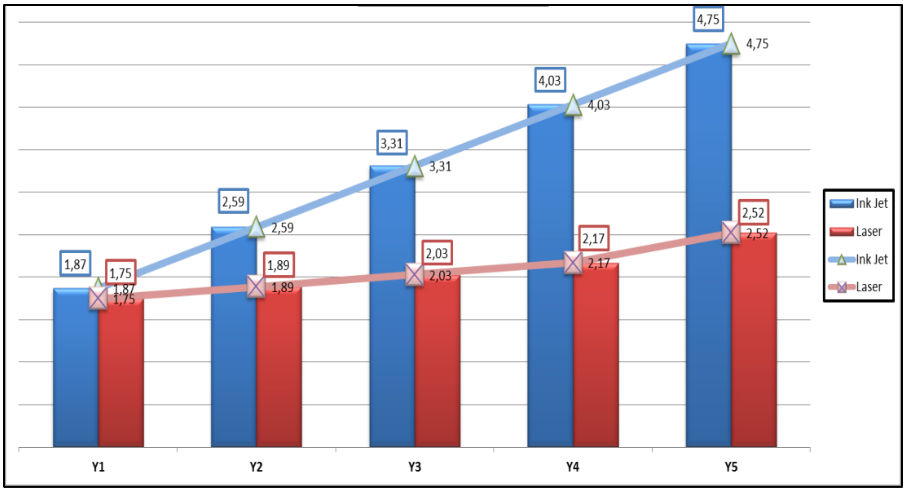


Fig. 82 Compared cumulative net margins over 5 years and for 1 sale.

So if the figures are in favour of laser compared to inkjet as far as turnover and gross margin are concerned, the year to date NET margin over the period clearly shows that SCP net contribution is almost twice the one of laser.

4.2.1.4 *2nd series of curves*

Let us go further into the financial performance comparison. We do not refer this time to each printer sold, but we will make the calculations for the overall installed base of the 2 technologies.

This second series of curves shows the evolution of the relative contribution of 2 installed bases over 5 years: 1 inkjet installed base and 1 laser installed base.

- We go back to the previous data.
- We apply a yearly increase of 30% ("official" growth rate, see after)
- We apply the relative SCP / CO^2 market shares
- We consider the margin level generated by each technology (yearly and cumulative) through its recurring revenues.

	A1	A2	A3	A4	A5
Evolution installed base Number of printers CIJ	85	110	144	187	243
Evolution installed base Number of Laser printers	15	20	26	34	44
Revenues evolution from Installed base CIJ (Per printer in K€)	2,4	2,4	2,4	2,4	2,4
Revenues Cumulative evolution CIJ (Per printer in K€)	2,4	4,8	7,2	9,6	12
Revenues evolution from Installed base Laser (Per printer in K€)	0	0,7	0,7	0,7	3,5
Revenues Cumulative evolution Laser (Per printer in K€)	0	0,7	1,4	2,1	5,6

Table 21 - Comparison Laser vs Inkjet: Installed base evolution and revenues per printer over 5 years

The previous figures are leading to the following curves:

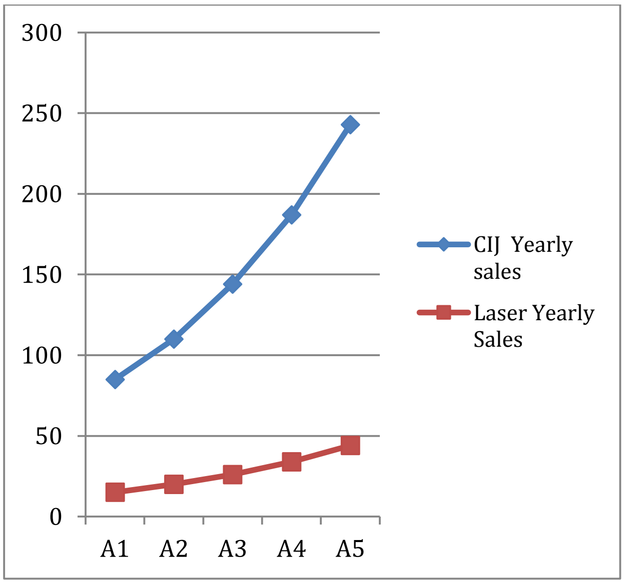


Fig. 83 Installed base theoretical evolution Laser vs inkjet

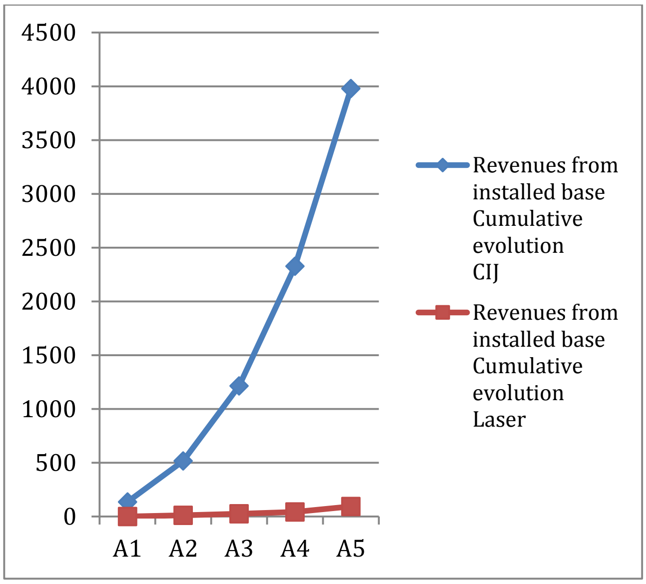


Fig. 84 Revenue cumulative evolution Laser vs Inkjet

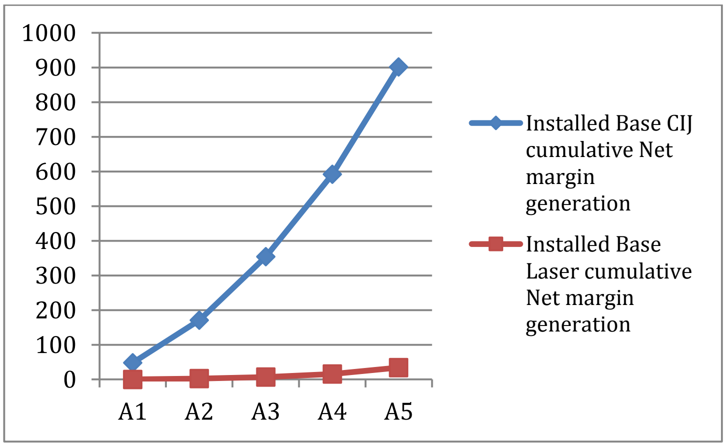


Fig. 85 Net margin cumulative evolution Laser vs Inkjet

We thus obtain the comparative development over 5 years of the turnover, the revenues, and the net margin from, on one side a laser installed base, and on the other side from a theoretical inkjet installed base.

We mention "theoretical" for our calculation to build the curves is based on data of market surveys claiming a yearly growth rate of 30 % for coding devices in the 80s.

The theoretical evolution of net margins for Laser vs CIJ once obtained, we aim at simulating what would have been inkjet evolution with the net margin level of Laser.

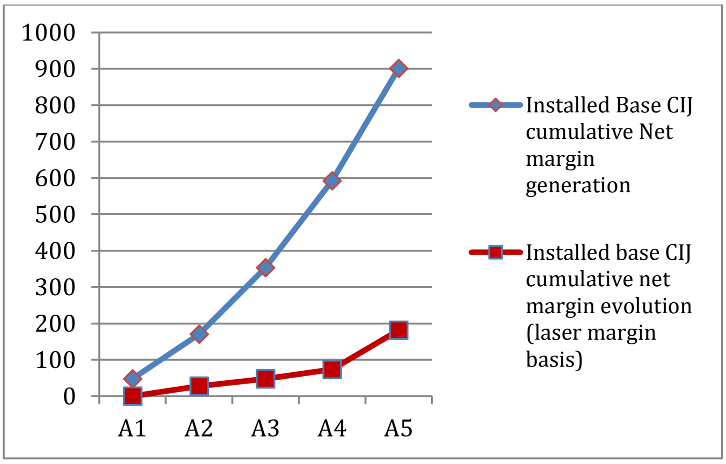


Fig. 86 Cumulative net margin evolution according to margin level

Above is the result we obtain by applying the CO^2 laser margins to the theoretical installed base evolution established for SCP (Imaje).

It shows how we would rewrite history by duplicating laser evolution and performance on SCP!

If we have established that not only the net margins were well the ones initially applied to inkjet – and therefore far superior from the laser ones- we also consider that the installed base evolution was considerably above the “official” 30% annual growth!

What we intend to demonstrate in details.

The necessary calculations are aiming at accurately evaluating the consequences of the inkjet rate of growth (clusters) on the performance of firms in microfluidics.

4.2.2 Method and Data

We go back to the previous elements. And we detail:

4.2.2.1 *Datas on Margins, prices and ratios*

- Goss Margin on fluids and consumables:
  - Ink (SCP): 80%
  - solvent (SCP): 75 %
  - CO^2 gas (laser) : 70 %
- Gross Margin on the device: 68 % (ink jet) / 40 % (laser)
- Gross Margin for each maintenance operation (Manpower 50% - Parts 70%)
- Maintenance / yearly cost for SCP = 2/3 inks and solvent vs 1/3 training and maintenance
- Net margins
  - printers = 11 %
  - Associated fluids = 35 %
  - Service = 20 %

The following information is based on Ink jet manufacturers' price lists 1995 and experts' archival notes:

- Printer S4 type (Imaje): 11,7 € (9 K pounds / installation included)
- The figures show a steadily downward trend of selling prices: When 9 K pounds was the price of a standard SCP printer in 1995, it was 15 K pounds 10 years ago!
- SCP inks (alcohol or MEK based): 20 - 50 pounds / litre.
- Price of a laser printer: Around 35 K€.
- The pricing of lasers in the mid-nineties amounted to 3 or 4 times the price of an SCP printer, once installed.

We add the Prices released by Imaje, in April 2014;

	CUS	REP (Enduser Price)	Net price	Margin on net Price
Ink mek black 5157-E	31,37	330	247,5	87%
Ink mek black 5157-E	39,9	170	170	77%
Printer GEr	2210		6907	68 %
Printer ITA	2210		8609	74 %
Printer SPain	2210		5555	60 %

Table 22 - Updated SUC and prices

Enduser Price = list price

4.2.2.2 *Consumption facts*

We defined in Table 7, and for the period we are surveying, CIJ equipment and CO^2 laser equipment prices. We now intend to compare in details the relative running costs.

- Annual running time of a printer: 2000 hours.
- Calculation base for the messages:
  - 5 printed characters
  - 100 messages per minute
- Annual total running costs: between 600 and 1600 pounds.
  - Adopted figure: 1095 GBP; i.e. (1580 + 610) / 2.
  - Consistent with another source (Videojet Survey 1995) considering 1303 € as the yearly cost of use.
- ***laser CO^2 : consumables ≈ 2% of the printer price (CO^2 gas)***

4.2.2.3 *Change rates*

To be able to compare by using different sources of information, coming from various countries and covering sometimes different years, we had to restate the exchange rates on a common basis.
It is what we have done, by referring to historical data.
For that purpose, we used mostly www.forexticket.ch/fr/conversion/monnaie-GBP as a source and reference.

But this survey was tricky for other websites were rendering approximate (and false) results!

Some websites like fxtop.com (« conversion de devises cours passés »),indicated : « 1 GBP = 12,60 FF » in 1995. But this is only a *theoretical rate!* This site is indeed just giving *indicative rates* for years before 1998.
Another broker, also insufficiently accurate, was calculating the rates with XEU (European Currency Unit) as the reference; leading to the ratio 1 GBP = 1, 192755 XEU and thus 1 GBP = 7.714025 FF (!), and still for 1995: 1 GBP = 1.69687 €.

In a nutshell, using the most reliable source of information mentioned above, we consider the following rate for 1995: **1 GBP = 1.92 €.**

So we got the figure that we were looking for.

But, besides, we were interested in underlining the difficulty to reach the correct figure and also the fragility of conclusions – in cases like this one ***- if the data mining is not fiddly enough.***

4.2.2.4 *An annual growth exceeding 30% per year*

2 series of information are explaining the rate of growth for laser and inkjet respectively:

- The Market evolution: For the 2 technologies, we consider a set increasing of over 30 % per year since 1985 (Domino Report 1991, p.3: "The compound growth of sales exceeds 30% ").
- The share of the 2 technologies: It remains constant in the ratio 15/85 the early years. For 100 sales of equipment, 15 laser versus 85 ink jet installations.

When we take into accounts these facts:
Yes, the laser market increased in the order of 30 % per year in the early years.
It was a very strong growth for a while.
But the growth of laser was thus well linear and not "explosive" or exponential (see below).

The growth of inkjet, in its early years, was almost exponentially instead.
And, in any case, linear nothing, contrary to what had been sometimes foreseen or claimed in surveys:
As an example we can refer to the customer research "Market for Printers and consumables for product identification marks and codes", mentioning a growth rate of the order of 20% in the early 1990s.
This is the kind of cases where average growth is false and where, anyway, considering the average is introducing a bias.

Proof: We can approximate the inkjet market growth at origin by the numbers of printing "heads" installed.

And as Imaje corp. was representing 70 to 80 % of its domestic market over the period, the number of Imaje heads installed should reflect by itself the evolution of the whole market originally!

That is to say:

Year	1982	1983	1984	1985	1986	1987
Installed base (number of heads SCP)	4	100	450	1100	1720	3200
Installed base (number of laser heads)	1	15	20	26	34	44

Table 23 - Evolution of installed bases Inkjet vs Laser[5]

[5] 30 % evolution for laser

So the evolution of the SCP inkjet installed base was drastically faster than the one considered above in table 21. Besides, it should also be noted a significant evolution and a very different perspective for the profitability of actors in the context of the installed base growth.

Indeed, the share of turnover related to consumables in this progression is following a constant increase over the period.

And the ratio versus laser is quickly broken!

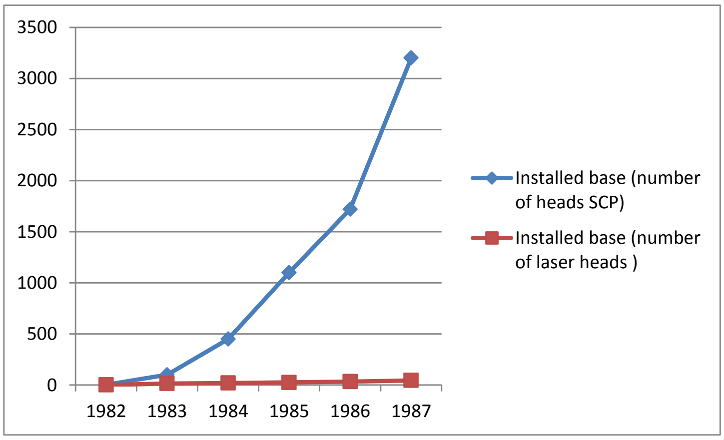


Fig. 87 Installed base evolution Laser vs Inkjet

Cumulative operational margins well above the ones of laser, plus an installed base evolution far stronger than estimated: This once stated, how could one then consider the market share of laser vs Inkjet as constant over years?!

We stand for the idea, relatively to the market shaping theory, that the outstanding resources generated by the CIJ technology (single nozzle!) enabled directly a spectacular growth of the inkjet market share over laser!

Installed base net margin yearly generation (K€)						
Year / Technology	1982	1983	1984	1985	1986	1987
SCP Inkjet	7,5	190	913	2381	4008	7222
Laser CO^2	1,8	26	37	48	69	82

Table 24 - CIJ vs Laser cumulative net margin generation.

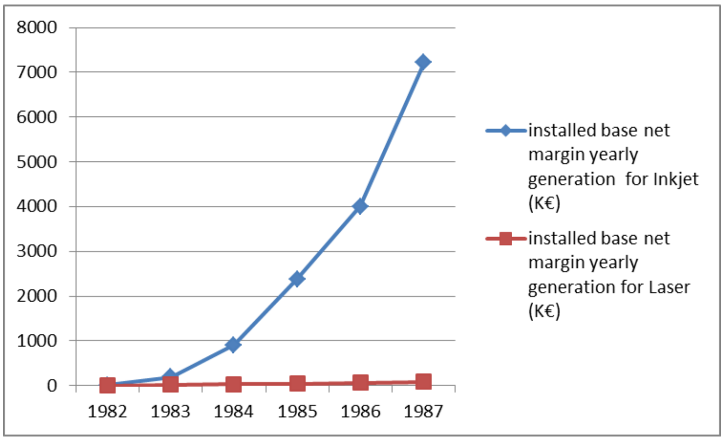


Fig. 88 King Kong effect data. Installed base net margin yearly generation.

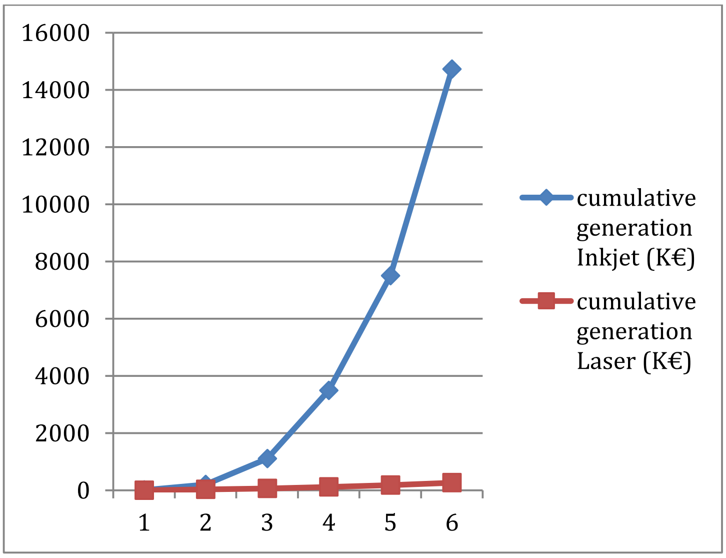


Fig. 89 King Kong effect data. Installed base cumulative net margin generation.

We then go further with the figures exposed in the “installed base” table above (table 24):

As we are interested in an evolution, it is quite natural to look at the differences in quantities from one year to another. That leads to the following table:

Gaps	E1	E2	E3	E4	E5
Years	82 → 83	83 → 84	84 → 85	85 → 86	86 → 87
Printers	96	350	650	620	1500

Table 25 - Measure of gaps in sales from one year to another

But this table does not enable to conclude (because of E4!).
Indeed, we cannot derive from it any evolution that would be satisfactorily in terms of parameters and modelling.

We carry on nevertheless in the logics of evaluating the differences between years, taken two by two.

The conclusion is a new table (Table 26):

Gaps	E'1	E'2	E'3	E'4
Calculations	**E2 –E1**	**E3-E2**	**E4-E3**	**E5-E4**
Printers	**250**	**300**	**0**	**900**

Table 26 - Measure of gaps in sales based on 2 years sequences

This time, the 3d column, E3' namely, appears as problematic.
Because the year 1986 is like slowing down the growth trend clearly visible in the first years.
And this slowdown is still more obvious when one measures the gaps between the various gaps (see above)!

If the figures attached to the year 1986 were superior, we would have seen appearing an arithmetical progression in the table number 25. The gaps between the various gaps would be thus linear. Or more accurately we would get an arithmetical progression with 250 as starting value and 50 or so as yearly increment.

Hence the formula: $$E'n = 50n + 250$$

Equation 7 – Early model for Inkjet installed base evolution

At this point it is very interesting to notice that the sales results for 1986 and 1987 are in a way artificially minimized. Indeed, the turnover during these two years was affected by the impossibility to deliver in less than 6 months the orders passed by customers. For the demand was spreading in such an epidemic way, that the supply chain of Imaje was not capable to face the increase in the orders' portfolio!
Associated logistic issues were numerous: from production bottlenecks to lack of manpower without mentioning procurement difficulties.
That brings additional support to our conclusions from the figures collected about the evolution rate in sales and profit. Besides, that illustrates one more time the importance of looking carefully at the reality to see appearing new pieces of information.

Let's then go back to the gap of differences:

$E'n = En+1 – En$

$= Tn+2 – Tn+1 – (Tn+1 – Tn)$

$= Tn+2 – 2\ Tn+1 + Tn$

Then **$Tn+2 – 2\ Tn+1 + Tn \approx 50n + 250$**

This last equation spurs to look for Tn as a mathematical expression comprising terms of the third degree; with a dominant coefficient equal to 50/3.

For, according to a result concerning linear recurrences, the only expressions potentially satisfying the conditions of the recurrence equation above are expressions comprising third level terms.

Just notice that such polynomial expressions are not always leading to linear solutions! [15]
So let's look at the equation representing the curve of revenues based on the Inkjet CIJ installed base.

The integration twice subsequently of the equation: $Tn+2 – 2\ Tn+1 + Tn \approx 50n + 250$

This repeated integration induces well a 1/3 factor with a 50 coefficient.

As a result, the formula giving, according to our model, the number of heads on a yearly basis: This formula will be polynomial from the third degree and with a 50/3 dominant coefficient.

Thus by taking as a starting point a "0" year (that would represent the initial column in the different tables), and by considering that the value Tn of the installed base for the year n is defined by:

Tn = 50/3 x n x (n + 1) x (n + 2) + 4

Then, if we develop, we get a third degree function:

$50/3\ (n^2 + n)\ (n+2) + 4$

$= 50/3\ (n^3 + 3n^2 + 2n) + 4$

Given that 50/3 is +/- equal to 16,
we thus obtain for Tn CIJ the following formula:

$$\mathbf{Tn = 16\ n3 + 48\ n^2 + 6n + 4}$$

Equation 8 – Model for CIJ installed base evolution

As a consequence, we observe that the result is nothing else than a polynomial form of the 3rd order.
We are not dealing with a geometric progression, neither with an exponential growth.

But in any case, we are facing a kind of growth very different from a linear progression.

We are not in a linearity pattern.
And that is what we wanted to demonstrate.

Comparatively, we get: **Tn laser = A + (n-2) (M' + F') + (n-4) S** (with n>4)

This equation describes a complete cycle (initial purchase + maintenance over the 4 following years after buying; source replacement included).

With S = income generated by the replacement of the laser source (after 4 years).

So, with n = number of cycles and M = M'+F', we obtain:

$$\mathbf{T4n+1 = A + (3M + S) \times n}$$

Equation 9 - Model for CO^2Laser installed base evolution

Check: If n = 0 → T4n+1= T1

After all these sequences of calculation, it has come to a kind of tipping point. A point where we make emerge a key-concept related to OP: The concept of ***outstanding recurrence.***

This exceptional recurrence brings to a level of value capture out of the ordinary.

At this stage, we have to remind the contribution to the level of value capture coming from fluid sales only:

Net margin on fluid sales > 30 %. Something outstanding

Besides, this exceptional value capture is not without creating a vicinity between our research about OP and the works also conducted on Hyper Growth (Cassia and Minola 2012), and on super-growth companies (Tonge 1998).

Hyper Growth as we discuss it as an illustration of OP, could be compared to the image of a fire spreading quickly. We know the variables explaining the diffusion speed of a fire:

- A fuel (it would represent in our case the market with all the potential customers).
- A level of initial heat (The very creation of the company).
- An oxidant (matching the capabilities and resources committed by the company).

What kind of curves could represent this type of diffusion? We will not be surprised to sliding back on "S" curves (Daudé, Langlois 2004).
Indeed, the "standard" model of fire and innovation diffusion as well is fitting the general model of diffusion (geographic / logistic)!
To continue on this metaphor of dynamics of fire: We know that the effect of combustive is conditioned by the moisture of the air, the quality of fuel; but also by the force of the wind. What would correspond well in our model to the King Kong effect (or "Big Bang", Bala Chakravarthy, SMS Geneva 2013) produced by the "available resources" within the meaning of Cooper (Financial and Human Initiators, Cooper, Gimeno and Woo, 1994).

However, even while considering when plants are burning the reserve of energy they contain, undoubtedly we would not come all the same at the model of recurrence which underlies our reasoning!

Indeed, whereas the diffusion of the fire progresses, it would be necessary to already imagine in parallel the trees on fire continuing to be consumed **with the same intensity** while always more new ones ignite. This to illustrate the extraordinary recurrence mentioned all along this chapter.

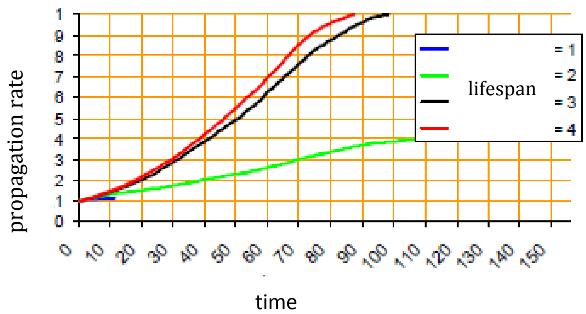


Fig. 90 Diffusion dynamics relatively to lifetime of vectors (evolutionary dynamics)

Inspired by an article from Daudé and Langlois (Diffusion Shapes, Geopoint 2004)

Now leave the general dissemination theme that could lead to suggestions such as NORMALIZE (with quantitative standards) dissemination phases of an innovation or growth of a business.
And let us return to the recorded exceptional recurrence.

4.2.3 Outliers and recurrence

Analysing ink jet clusters, we have shown that recurrence is arsing mainly from consumables.
This leads to stress the importance, as such, of the business model not only generally as a lever of a new company's performance, but more specifically as a cause of the "technological success"!!!
In this sense, the role of consumables is just one example of the significant properties of a BM.

We would also like to point out that the very general concepts such as recurrence itself, are not enough to CHARACTERISING performance.
It is only after fully estimating the relative levels of contribution, through the different cases of recurrence figures analyzed, that the different categories appear.
In other words, to make manifest performance levels, you must associate them with a numerical value based on identified recurring patterns leading to a rating system.
So we will not be satisfied, subsequently, to evoke a "rapid growth" (Hambrick and Crozier 1985), or "sustainable growth" (Baldwin et al. 1996), referring to the growth and profitability as the two essential dimensions of company performance (Davidsson, 2005; Steffens et al, 2009.). We will strive to define each category by a numerical interval.

This said, the representative group of OP nevertheless appears obvious!
Indeed, having previously established that recurrence was from consumables, and considering our detailed approach, in "layers" of inkjet technology, we will not be surprised to find the following results:

4.2.3.1 *As far as Ink Jet is concerned, OP is specific to CIJ!*

We will first establish that if we just consider a very general technological level, the conclusions that we can draw are doubtful and uncertain. But, instead, when we work at CIJ level, O.P. appears. In other *terms, from our conceptual pattern, O.P. is specific to CIJ!*

We have already contributed above to this theme (see the part: In Search for Outstanding Performance).When we validated the bond between disruption and performance. We have also underlined the limits of these considerations and given examples of solutions wrongly qualified as disruptive.
All sorts of elements that already sustained our *layers' methodology*, at technological level first; and then in the following pages as far as performance is concerned.
Because the detailed-, careful-, in-depth ***refined study*** of the techno is contributing to the comprehension of Outstanding Performance.
This comprehension in detail, indeed makes it possible to establish the link between small branches of the technological tree and different levels of companies' performance.
This approach thus has a predictive value.
However as we already indicated: nothing resembles one technology inkjet more than another technology ink jet!

Let us consider for example various inkjet technologies represented in the studied clusters.

Ink jet Technologies	Typical price level for 1 sale (Selling Price)	Trading margin generated by 1 equipment for a full year of exploitation	Comments
DOD piezo water base	4,5 K€	0.36 K€	Ink cartridges No additive
CIJ single nozzle (Deflected)	12 K€	2.40 K€	
Binary jet (CIJ)	50 K€	6.55 K€	15% more consumption than deflected
DOD valve jet	2,2 K€	0.50 K€	
DOD piezo UV	50 K€	2.07 K€	4 colors

Table 27 - End user prices for various ink jet technologies [6]

We make the assumption that the variance around these values was not very strong.

Indeed, in the first years of appearance of these technologies, the number of competitors is reduced, positive the growth of the market and thus weak the pressure on the prices.

Assumption. Are:

X = level of price of equipment X at moment M
$\overline{X}$ = prices of equipment X on average
N = many periods
N < 10

Then, we consider that the variance, i.e. the sum from i=1 to N, to the second power: $\sum_{i=1}^{N}(X_i - \bar{X})^2$, and divided by N is nearing 0.

what we write in mathematical terms:

$$\sum_{i=1}^{N} \frac{(X_i - \bar{X})^2}{N} \approx 0$$

Equation 10 –variance formula applied to sample

Again, we make the hypothesis of a variance close to 0, insofar as the market related to these technologies is very developping and bullish at the time of the study, and the number of competitors reduced to some.

There is thus no risk of strong trend pressure on the prices. The variations in the selling prices being the result of the simple pressure of the negotiations in the buying process during the time.

[6] Example of calculation detailed in annex.

4.2.3.2 *Warning!*

The previous reasoning has a limit. The very one we higher mentioned (in the chapter Outliers and Outstanding Performance: King Kong Effect): It is necessary that the initial condition is met. Namely an effective matching between sub-technology and the application considered.

Thus, in the case of the company ELMJET (U.K.), the fact that the potential value created by customer be large, was not enough to generate an additional outlier.
The OP was not with go. Elmjet indeed met many difficulties of growing.
Technical problems on the one hand, related to a technology (Binary Jet) very "sensitive".
Problems of markets also. The end user's level of expectation was very high in the industry targeted by Elmjet (Printing Industry) when customers where less demanding in the coding sector explored by CIJ.

In a general way, a disappointing technology on veto criteria ("Must-Be" functions, Kano, 1984) constitutes a constant limit with the reasoning on the OP.

It could prove interesting consequently, and in complement, simply to invalidate the "classical" postulate on the positive relation between Innovation and performance on the basis of SME's samples!
The database on the inkjet clusters which we worked out could underlie such a job: A statistical task which would show that the innovation generally leads to "marginal growth" or "failure" and not to HG (Hyper Growth).

In a way even broader, our remarks are not limited to affirm (or to reaffirm):
- "it is a question of growth market and resources",
- or: "it is also the managers' capacity to using these resources well".
With respect to the literature on Performance, our conclusions are thus not completely banal.
The originality of our proposals is due precisely to the fact that the OP does not seem: Neither directly related with the quality of the managers, neither with a simple question of resources in the general sense, nor with a question of only growth market (on which the laser, for example, was also positioned).

Symmetrically, it should be noted that the OP deletes many "insufficiencies" related to the classical variables of performance (quality of the managers, quality of service, good management…).
The OP has for example a capacity to delete the errors and to breach the good management practices: Thus the unreliability of SCP equipment at their beginning did not prevent the development of the market at a rate higher than 30% annual!

Same manner, it appears that when the performance is exceptional, it is necessary to take into account other elements than the only effectiveness of the couple technology/application, this would be on a very specific level.
It is also a question of outstanding value capture (Business Model).
And in this sense, we subscribe to Teece's argument (1986): value can be appropriated by (essentials) complementors.
What is right with Teece at offering level is also true when considering value at strategic level.
And CIJ, thanks to its speed, could be considered in the 1990s as an essential strategic complementor of a production line, enabling for a moderate investment cost to speed up a whole plant tens of millions worth.

We wish to integrate, within the framework of a very classical scientific approach, many recent or historical advancements in the management of technology and industrial engineering fields to shed a very focused, but - we hope for it – new light, on Hyper Growth.
This while trying to supplement the existing conceptual scheme by starting from very accurate questionings on what makes and contributes to explain performances of exceptional companies. At the time of starting up and after a couple of years after the business launching.
Questionings leading to inductive reasonings. Interrogations on the value and the price, for example: Why is the customer ready to pay this value? Why is the customer ready to pay this value (EXCEPTIONAL) and in a recurring way (RECURRENCE)?

What leads us to add the idea that the OP exists only because the solution in the root of the OP has an exceptional leverage effect.
An exceptional leverage effect on the value for the customer:
- On usage values for the customer (case of the ink jet).
- On image values for the customer. As such, the case of luxury products would be consequently a source of additional developments around the OP, through the notion of Esteem Value (L. Graillot, 1998).

In this direction, our analyses come to reinforce the theory of disruption. The exceptional leverage effect corresponds to a technological solution which to some extent lifts 1 "bottleneck".

Because the new solution offered to the market has an immediate **systemic** incidence!

In other words, the action on 1 element (of competitiveness) releases a systemic effect: The OP comes from a "local technological solution" (i.e. on the level of a micro-economic element / i.e. 1 only company) which has a general incidence on the competitiveness of this company and consequently on the competitiveness of all the companies adopting the same new solution.

4.2.3.3 *A Business Model-type disruption*

But, as we saw, it is not question only of technology. The matter is *exceptional value capture*; thus related to a specific business model.
What is just, for us, like locating the OP within the following general outline of innovation, and in particular of disruptive innovation:

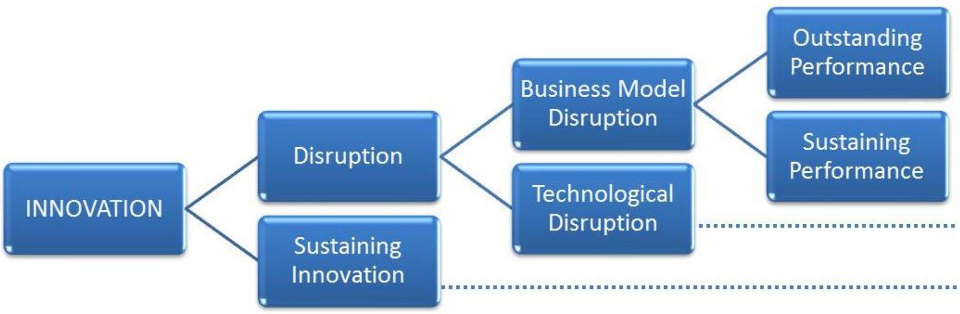


Fig. 91 Diagram: OP positioning in the general innovation outline.

4.2.4 Exceptional performances: between chance and strategic approaches.

Criteria usually underpinning the performance of innovative companies are prerequisite for OP.

We add the Idea that it is necessary to think differently when the data are EXTRA-ordinary.
Same manner as at the level of the microfluidic one, the non-Newtonian fluids do not answer the same physical laws as the "classical" fluids; same manner the outliers in performance answer specific diagrams of evolution.

There is something behind (there is always "something" in the OP), there is something behind Outstanding Performance that is really specific to each case. The Outstanding Performance cannot be put in a complete model. On the basis of the knowledge available nowadays at least.

So: Highly useful and in a sense NECESSARY, but very difficult to be predictive about OP.

On the analytic side, we can however describe / list the set of variables that play a role in the OP.

But OP reason is perceptible only to a level of intimacy with the subject; like the shades of blue for the experts of Aubusson, or the snow for the Eskimos which use tens of words to indicate it, as like to affirm the scholars, specializing in personal development…
This could refer to the concept of layer on which we do insist.

Until now, we could characterize the disruptions as well technological as well as of Model business. But this characterization did not make it possible to conclude on the performances of the companies acting like vectors from a new technology.

Let's take an example: We describe and compare below 2 systems, one displaying pre-inkjet workflow and, the other one, Inkjet workflow

Fig. 92 E.g. of tampography (« pre- ink jet ») workflow (Dickson training)

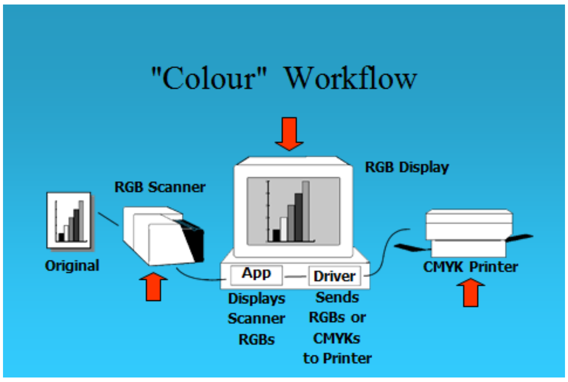


Fig. 93 E.g. of inkjet workflow (Dickson training)

By studying the 2 technological principles presented above, it proves very quickly that we have to make with 2 radically different technologies. It is enough for that to underline the key difference separating one ("classical") *contact* printing technology (Tampoprinting) from a *contactless* digital technology (Ink Jet).
But if the degree of rupture that we illustrate (see diagrams), between ink jet and tampography, indicates quite well radically different technologies and processes, it is however overly general and indirect to conclude on the performances of companies promoting one or the other solution!
It is the specific positioning of each company on such or such alternative and variation of the mother-technology that will be predictive of performance.

We then change "layer" of reasoning.

Likewise: My banker once told me: "The actions are riskier, but consequently they pay in the long run"!

He established a quasi-mechanical link between the risk and the performance.

It is from false postulates of this type that so many researchers leave when they speak about exploration: Riskier but more over time pays.
However, in the case of the investment adviser, it is false: my savings passbook paid more over 20 years than my portfolio of stocks!

This wrong advice is not surprising. Because my banker is not able to measure the specific risk at the time T and for the period P to come, of each support he is advising. And 20 years ago, he underestimated the risks related to the stock market.

If the "average" banker adopts a superficial approach of concepts at the heart of his job; it is that these concepts require a very long work, very concentrated, very careful – a true research - to be understood.

Let us wish that this form of cure and commitment will not be lacking for the mass of the articles of management.

We want to pursue our analysis on the OP to the end. Therefore, we should, in particular, specify the criteria at the origin of an **exceptional value capture**.

This exceptional value capture is, by definition, a rare event. And we will see that, if the corresponding factors of performance are not rare by themselves, their combination is. Which factors? Which synthetic criteria?

a. A specific "technological niche".
b. An application enabling to maximize the perceived value system (BtoB or BtoC).
c. A « dream » aiming at changing customer's life.
d. A buoyant sector.
e. Ambitious entrepreneurs.

With these criteria of the OP, we make a point of adding an element which takes part in the dynamics of the system.
It is about an element suitable to reflect the chaotic system and environment in which the companies operate in this beginning of the 21st century: We will call it the *"hidden variable*" as conceived by D. Bohm (1951) in his works on unpredictability in Physics..

Detailed criteria:

i. A specific "technological niche".

It is a topic on which we would like to add our contribution to the building of the theory of disruption.
Indeed, we noted that the OP does not appear on the level of a technology in general (generic technology) but always through a VARIANT.

A variant specific to the technology considered, as demonstrated about inkjet.

This *fractal* approach is key for us in the understanding of OP.

We refer to fractal as defined in the article on Innovation and Performance: *Outliers and Russian Dolls (Calisti Tucci Wieser, 2014).*

The fractal nature is related to the enshrining of super-powerful technology in the various technological layers such as they are represented in the ***bush*** of the technical evolutions (page 101 and after in this dissertation).

The company positioned on the technological branch at stake occupies a kind of "technological niche" corresponding to a particular know-how. The super-performance is expressed on a given application as we will specify it.

ii. An application enabling to maximize the perceived value system.

In this case, the application is defined as the satisfaction of a well-identified need. The Perceived Added (extraordinary) Value covers:

1 Exceptional levels of operational margin.

2 They lead to strongly stimulate the suppliers' motivation. The offer is thus stimulated in quantity and in quality.

3 Suppliers' motivation goes along a significant motivation on the demand side. For the demand appreciates the value brought and is ready to pay the price for it.

4 The disruption at stake is thus leading to: Large market shares *and* premium price levels as well. This is –per se- something exceptional.

All in all, the disruption noted on the definite application refers to a kind of derived system of value.
A value system derived from the pre-existing value system based on a business model type of disruption (Christensen, 2006).
This statement coincides with the recent results and improvements associated with the disruption theory as revised by Dyer (2011).

There is a real bond between this approach based on well-defined applications and the User Innovation theory.
When Von Hippel (AOM, 2012) makes the difference between "User Innovation and diffusion vs production innovation and diffusion", he takes other words to tell the same story.
Indeed, when he is referring to innovation by users as "free revealing / collaborative replication and improvement", he uncovers the linkage between very successful applications and users' interest.
For customers are keen to invest time and skills in motivating and useful tools and services.

When, besides, Von Hippel still, is mentioning "peer to peer" diffusion as a result of customers' interest and collaboration, he seems to put his own words on the role of "re-buy" that we develop below.

In the same way, if the world of competitive advantage is "getting increasingly complex", making *value appropriation* more and more difficult; this leads to *complement* more and more *focal offers* to bring the appropriate *value to user.*

It is in a sense the reverse side of what we stated ourselves when we underline the importance of a kind of hyper-adaptation to specific applications in order to maximize this same value to users.

We are then not surprised to consider that user innovation can reach 140 % of R and D expenses (Von Hippel AOM 2012).

iii. A « dream » aiming at changing customer's life.

From this point of view, a sociological approach seems suitable.

OP always conveys a sort of « dream ». In the way that a certain Steve Levitan , one of the creators of *Modern Family*, admits to being « an Apple fan » ; again in the same way and about the same company, the physicist Geoffrey West, former president of the Santa Fe Institute and one of the darlings of the Silicon Valley declared « I don't know anything about Apple as a company, but what I do know is that I love their products » (Inside Apple, A. Lashinsky,2012 p 141 and p151).

Such popularity is unlikely to be eternal but it accompanies success and doubtless contributes to building it up.
In any event it's in this context that we appeal to sociology regarding OP to connect an added value of image, of esteem and of subjectivity to the purely technical profits contributed by the radically new offer (i.e. disruptive).

Indeed, OP cannot be reduced to a « technical thing » in the sense of Calon (2007) and Latour (2006). Quite the opposite: OP is a real *performativity* vector.

At the same time it's also the result of a *performative* activity.
OP is a vector and result of performativity (Calon, 2007) in the sense that it gives the customer the feeling that what he buys will change the way he does his job (B2B) , the way he consumes (B2C), how he has access to his favorite hobbies or benefits from this or that service. Finally, it will have changed his life. Which in turn (positive word of mouth ...), encourages OP.

This, therefore, is how companies that generate OP raise the performances of their entire sector.

iv. A buoyant sector.

As it is question of disruption, and as it is question not only of offer disruption, but of Business Model - "It was not a Technology problem, it was a business-model problem."- (Christensen, *The Ongoing Process of Building a theory of Disruption,* 2006, p.43), we will not be astonished to consider and to note that the sectors on which the OP develops are overall developing sectors.

In fact, sectors where a technology is imposing itself at the expense of another. When considering a global perspective, this happens at the level of a generic technology.
If the (new) generic technology does not progress in market shares over the solutions in process of obsolescence, then the OP is not possible.

v. Ambitious entrepreneurs.

Not only do they need to be ambitious in their ego, psychologically speaking. Numerous behavioral studies report this personality trait through leaders' typologies. However, to contribute effectively to OP –and this is the point we want to make – they also need to have ambition in their decisions and in their company plans.

We could express this performance factor linked to leaders' abilities through a concept already used by Tushman and O'Reilly (Ambidextrous Organizations, 1996) and by slightly transforming it so as to consider « Ambidextrous Leaders » PLUS.

We therefore refer to a double ambition (thus ambidexterity):

1. An Exploration ambition: Which pushes the company to achieve significant and permanent improvements in terms of Products / Services. And in this, we are in line with the concept of Product / Service Leadership developed by Wiserma.
2. An Exploitation ambition: Which aims at achieving Operational Excellence, still in keeping with Wiserma's reasoning, and creates a high relative level of customer satisfaction.

To be complete in this strategic approach of the role of a start-up leader and manager, we combine with this double ambition the idea of high sensitivity to Customer Intimacy.

The ambidextrous entrepreneur that we envisage has a « third hand » that makes him ambidextrous "Plus". This third « hand » is his ability to communicate his brand's ambition to his customers.
A communication that can be both direct (through his own speeches) as well as indirect through the company culture that he implements.

4.2.4.1 *Showing that the market's choice is due so widely to chance in the cases reviewed*

As to the hidden variable[16] we were referring to above, according to us, it covers an element of **pure unpredictability.**

We could translate it by "chance", because it is really a question of taking into account a part of fate or structural uncertainty (Nate Silver, The Signal and the Noise, p.393), intrinsic to the exceptional situations.
There is always, indeed, an uncontrolled parameter in the situations of OP.
A kind of "resonance". An exceptional full resonance with the objective conditions as well internal as external. Just as a wooden bridge can collapse if a troop of people walk in time, at a precise frequency and this one only!

We noted that there is always "something" in the examples of OP which we listed. And that this something is specific to each of the stories.

Happily, this randomness, while impacting the combinatorial factors does not affect the relevance of it.

In other words, although impacted more or less by the "chance" factor; when the synthetic value capture criteria are operating, the OP is quite present too.

All this leads to the following synthetic criteria assessment scheme:

a. A specific "technological niche".
   i. Disruptive Offering
   ii. Partially Disruptive Business Model (disruption on 1 or 2 elements)
   iii. Totally Disruptive Business Model (disruption on all 3 elements)
b. An application enabling to maximize the perceived value system. (BtoB or BtoC). EBITDA:
   i. Outstanding (>= 16%)
   ii. Strong (> 5% - < 16%)
   iii. Low (=< 5%)
c. A « dream » aiming at changing customer's life – Turnover's growth :
   i. Outstanding (yearly growth > 20%)
   ii. Strong
   iii. Average / Low / No Growth
d. A buoyant sector
   i. Strong growth (for the whole sector / generic technology)
   ii. Average growth
   iii. No growth (or negative)
e. Ambitious managers / entrepreneurs.
   i. Product/service leadership level (exploration index)
   ii. Customers' satisfaction level (exploitation index)
   iii. Customers' intimacy level (brand preference index)
f. Hidden Parameter (if any).
   i. As an accelerating factor of the OP
   ii. As a delaying factor of the OP

The Synthetic Assessment Scheme can also be displayed in a table highlighting the criteria at the origin of an exceptional value capture.

Criteria	Metric	Value
Disruption level (Technological Niche)	Disruptive Offering	TBD
	Partially Disruptive Business Model	TBD
	Totally Disruptive Business Model	TBD
Maximization of the perceived value system	Low Gross Margin	TBD
	Strong Gross Margin	TBD
	Outstanding Gross Margin	TBD
Intensity of the customer's Dream	Average / Low or No Turnover's Growth	TBD
	Strong Turnover's Growth	TBD
	Outstanding Turnover's Growth	TBD
Sectors' evolution	No growth (or negative)	TBD
	Average growth	TBD
	Strong growth	TBD
Managers' ambition	Exploration index	Product/service leadership level (/6)
	Exploitation Index	Customers' satisfaction level (/6)
	Brand Preference Index	Customers' intimacy level (/6)
Hidden Parameter		As an accelerating Factor for the OP
		As a delaying Factor for the OP

Table 28 Synthetic Assessment Scheme

Table 28 summarizes the rating system enabling to get metrics and numerical values for innovative companies including outliers. And this is the result we were aiming at.

4.2.4.2 Conclusion: The outliers are not bias*!*

The current statistical approaches regard the outliers as "aberrant" values or not significant of a series. These events, however, have a real epistemological value. They can indeed reflect a specific nature of phenomena. The outliers are not only these statistical biases; they are also sometimes very instructive paradigm shifts of variables. This principle and this reasoning guided us.
The OP corresponds to outliers; they deserve to be studied.
They put into perspective the criteria of performance usually applied to the innovating companies.
As we stated above, the criteria usually underpinning the performance of innovative companies are prerequisite for OP. And we have established with the survey on European inkjet clusters that an outstanding performance was grounding OP.

So we can consider an equation showing:

OP = Business Model Disruption + Explosive Recurrence

So we can complete the matrix that we first stated above in the second part of chapter 4: Table 20 - Disruption taxonomy
.

Evolution in Revenue Stream	**Similar**	**Changed**	**Boosted**
Disruption Type	**Technological Disruption**	**Business Model Disruption**	**Business Model Disruption + Explosive Recurrence = OP**

Table 29 - Positioning OP within disruption theory

As we have seen all along this thesis report, most of the players in the field of micro-fluidics studied were viable.
But even if many different versions of the ink jet story can be considered, only specific variants of the microfluidics technology have led to an "outstanding dependence of the customer" (Marvin Lieberman / AOM 2012).

At this level, our findings could be generalizable to other consumable-related product industries (as such a big part of the economy).

But this work also enables further research to identify and characterize the OP in other industrial sectors than microfluidics.
At the beginning of the PHD work, NO DATA was available on this cluster, it was merely not existing (in the sense of performation used by Callon and Latour).

The gathering and building of data from scratch, if demanding on one side, enabled on the other side to catch unique and highly valuable information (without this first-hand information, the likely outcome would have remained non-apparent). Such as the revenue generated by customer according to the sub-technology involved and the application targeted with a given technology or the key role of recurrence

4.2.5 Outstanding Re-Buy

The Outstanding Value Capture in our case appears for a specific techno/application dyad (among other conditions). It is due to exceptional conditions for **Outstanding Re-Buy** (recurrence).

In the case of European ink jet clusters, The OP applies for all CIJ / applications couples and for them only.

Reminder: IF one changes the application or the technology used, then one loses the OP!

The Synthetic Assessment Scheme mentioned above can be used to make a quick performance analysis for a defined company.
It enables to test the possible presence of OP when considering a firm evolution.

We will then call the Outstanding Re-Buy: **Synthetic Criterion of Outstanding Performance** or **Synthetic Criterion for Exceptional Value Capture.**

It reflects, year after year after year outstanding EBITDA's levels.

In chapter 3 (validation of the link disruption/performance) we had noted the variation of value which could appear between companies radically innovating (effect pattern) and not- or sustainably-innovating firms (no effect pattern).

Now, we wonder about the reasons producing the exceptional recurrence (exceptional re-buy) when it is present. We validate its role in the OP.
With this intention, we measure, in the following chapter, the impact of this synthetic criterion of value capture on the performance of companies innovating in various contexts.

4.3 Checking the Validity of the Findings

We intend in this chapter to validate ***extrinsically*** our findings.

By testing our hypothesis on the companies belonging to microfluidics clusters, we previously demonstrated the ***intrinsic*** value (Yin, R. Case study Research. Design and Methods, 2003) of our conclusions about OP.

We have now to confirm these results by checking their “applicability” to various sectors and contexts (Yin R., ibid.); different from the ones already considered in our dissertation.
The dual validation comprising intrinsic and extrinsic checking enables to control the robustness of the theory.

As a consequence, we aim at showing the continuity of the findings and their permanent relevance, in the following cases:

- Companies belonging to the microfluidic sector, but positioned on a technology / application couple not represented in the clusters (case N°2 below).
- Companies belonging to sectors differing from microfluidics (cases N°1 and N°3 below).

So consider first a company within ***another sector than inkjet*** and regarded – according to expert judgement - as an outlier in performance (OP).

This firm is Asconit.

4.3.1 Case N°1: ASCONIT

Activity: Hydrobiology.

Date of incorporation = June 1, 2001

Does it match the synthetic criteria of exceptional value capture?

Let us look at the figures we gathered:

	2002	2003	2004	2005	2006
Turnover (K€)	300	745	1 068	1 880	2 802
EBITDA (K€)	32	26	-1.6	125	184
EBIT Margin (%)	10.6	3.5	0,1	6.6	6.6
Staff	7	13	19	29	42

Nota : Average Margin (Ebit) over the period = 5.48 % / Average turnover per deal = 20 K€

Table 30 - Historical data from company ASCONIT

Quick analysis of OP on the basis of the Synthetic Criterion for Exceptional Value Capture and on 2 additional performance criteria.

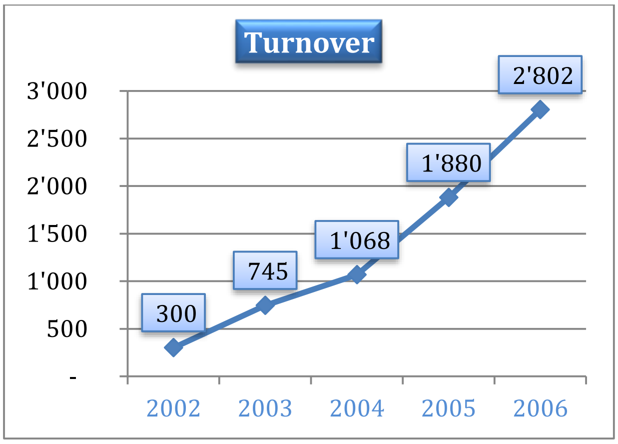


Fig. 94 Asconit Tunover evolution (K€)

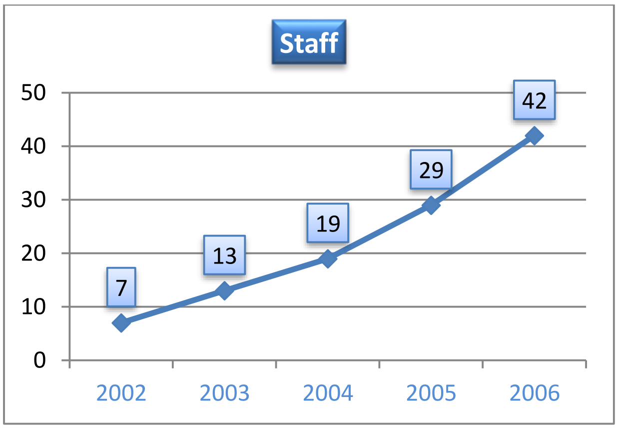


Fig. 95 Asconit Headcount evolution

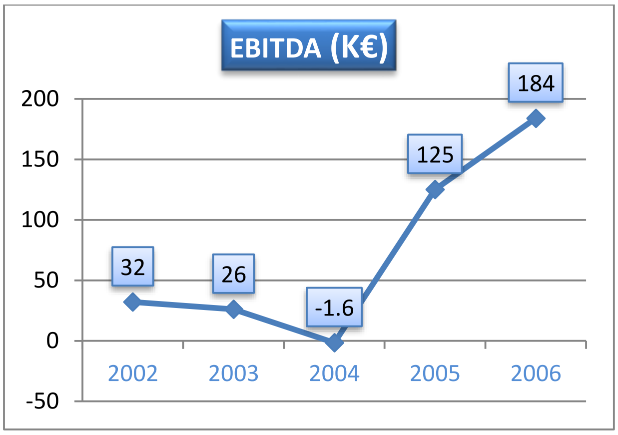


Fig. 96 Asconit EBITDA evolution

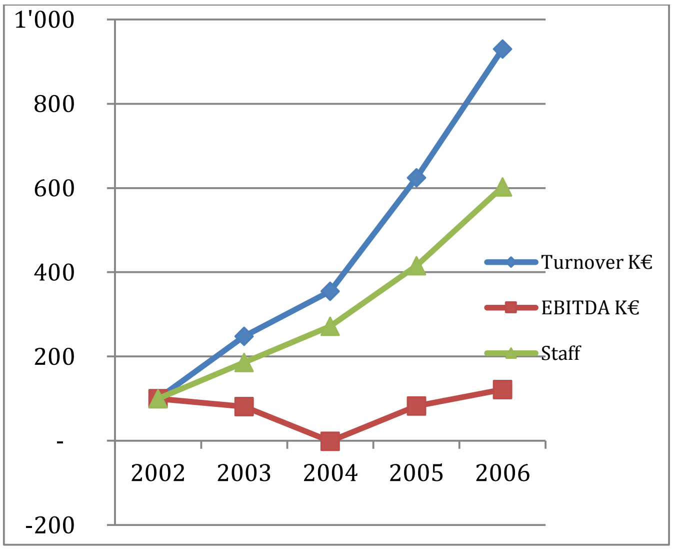


Fig. 97 Asconit Synthetic Chart (index base 100 / year 1)

VS ink jet: The following figures are presenting the position of Asconit if we include Asconit's curve among cluster's ones:

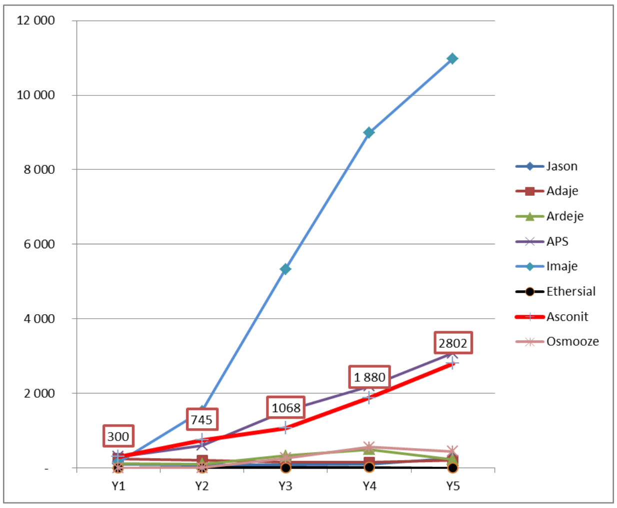


Fig. 98 Turnover: Asconit vs Inkjet cluster (K€)

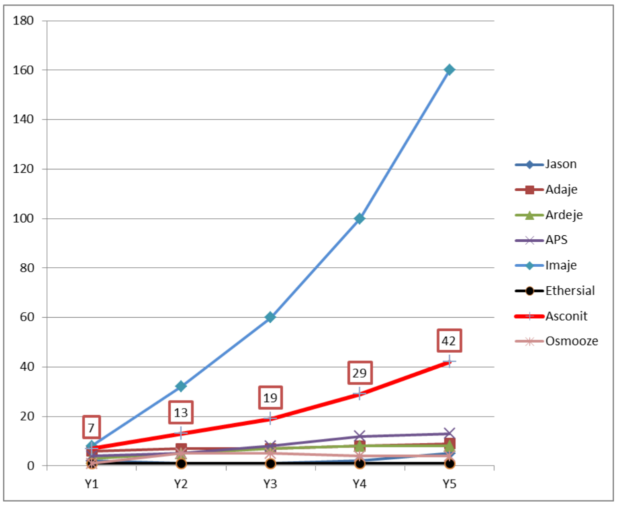


Fig. 99 Staff: Asconit vs cluster

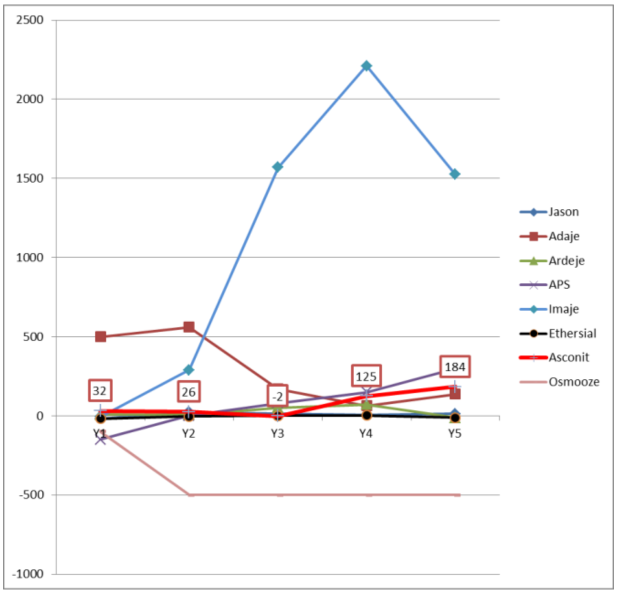


Fig. 100 EBITDA: Asconit vs cluster (K€)

As shown by the graphs and data above, there is a strong growth in turnover and staff for Asconit.

But this strong growth is NOT exceptional.

Does the development of Asconit refer to an exceptional value capture?

The answer is: NO.

In any case, there is no outstanding recurrence to be seen.

Conclusion:

No outstanding growth in terms of turnover and staff level → No exceptional value capture → No OP.

This supports and confirms the thesis.

Consider now a company in ***another application*** of ink jet technology (but different from CIJ/SCP), and regarded – according to expert judgement - as also an outlier in performance (OP): This firm is Impika S.A.

Does it match the synthetic criterion of exceptional value capture?

Does the Impika's development refer to an exceptional value capture?

4.3.2 Case N°2: IMPIKA

Activity: Development, manufacturing and sales of Digital Press equipment.

Date of incorporation: 1988

Let us now look at the figures we gathered:.

Year	2003	2004	2005	2006	2007
Turnover (K euros)	**759**	**900**	**2500**	**4500**	**5000**
EBITDA (K euros)	**+142**	**< 0**	**< 0**	**- 0.8**	**< 0**
Staff	**13**	**19**	**23**	**36**	**45***

Table 31 - Historical data from company IMPIKA (Sources: Various. See below).

* Nota: 8 M€ turnover were necessary to breakeven. So the loss, this same year, amounted to 3 M€.

All along this PhD process we faced difficulties to get the "real" figures about SMEs and historical data. So we had to use lots of different sources of information and time …
The main sources of information were the following: All data bases available at EM-Lyon , plus the Activa Data Base, plus experts, in several cases the founder of the company, sometimes the entrepreneur's personal adviser, plus 57 articles!.
Nevertheless, in the case of Impika, we still did not get the specific EBITDA for all the years of the surveyed period.
Fortunately, we knew that the figures for the missing year were negative. And that was enough to go on our analysis and conclude.

Quick analysis of OP on the basis of the Synthetic Criterion for Exceptional Value Capture and on 2 additional performance criteria.

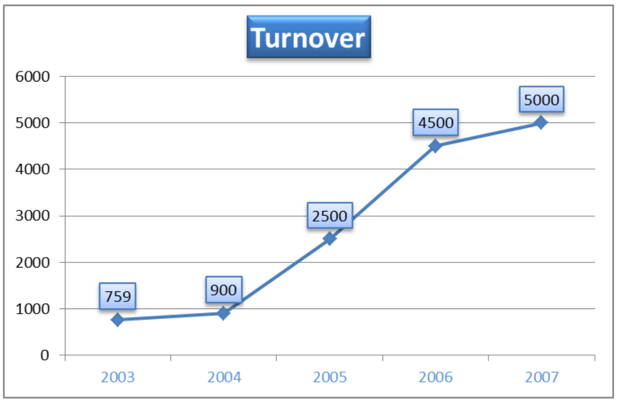


Fig. 101 Impika Tunover evolution (K€)

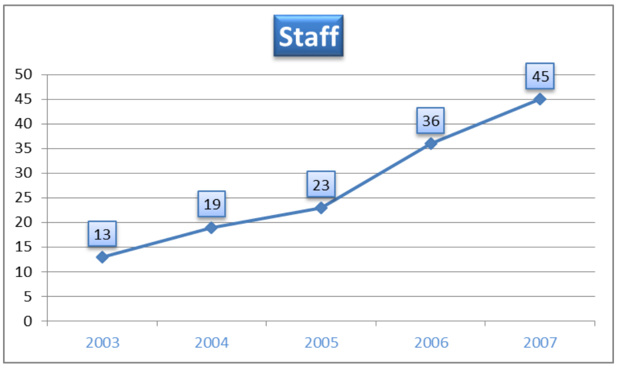


Fig. 102 Impika Headcount evolution

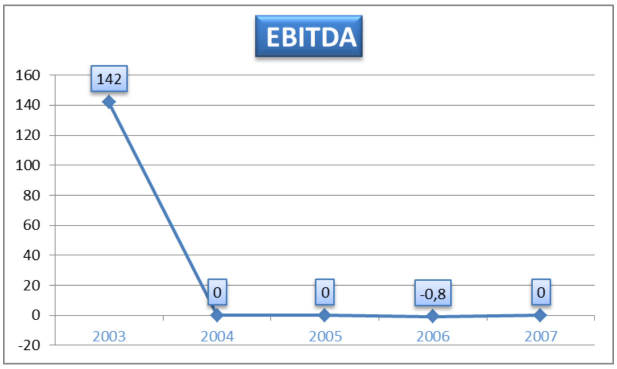


Fig. 103 Impika EITDA evolution (K€)

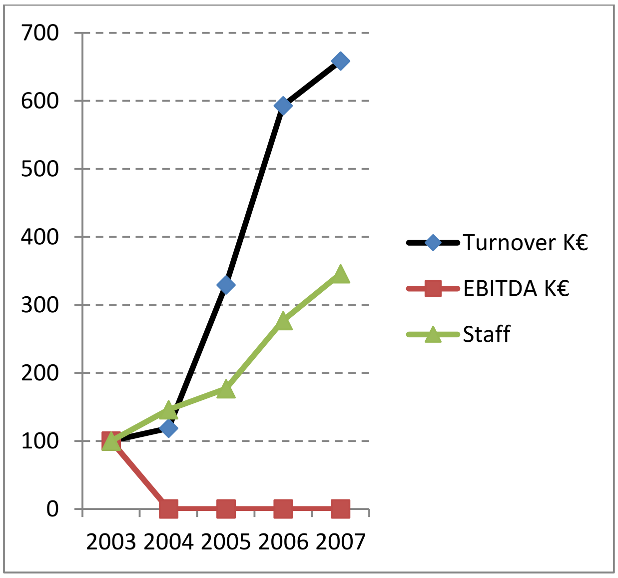


Fig. 104 Impika Synthetic Chart (index base 100 / year 1)

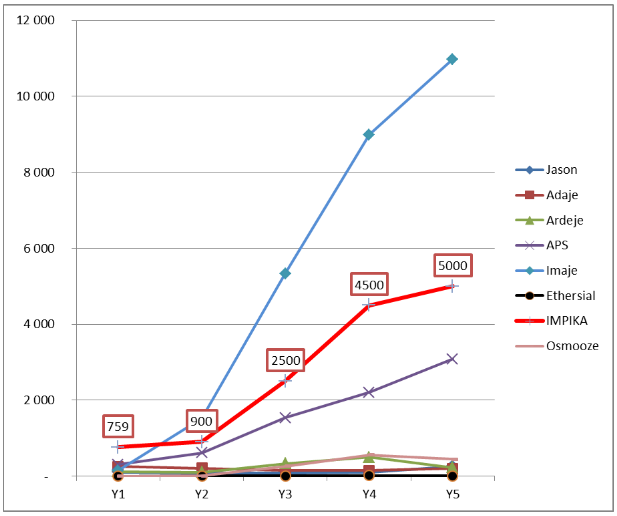


Fig. 105 Turnover: Impika vs Inkjet cluster (K€)

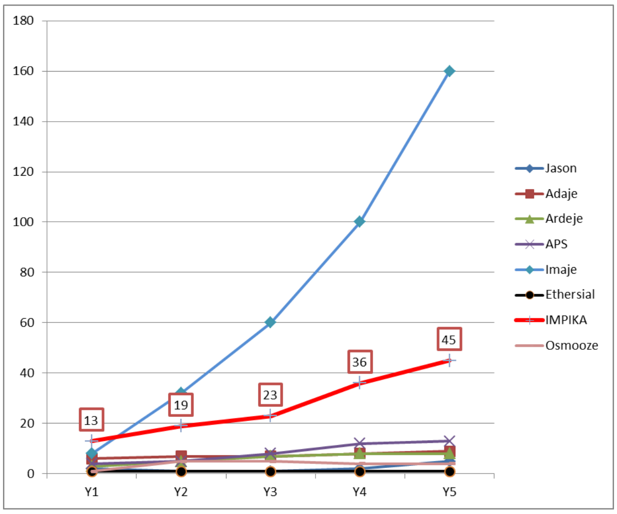


Fig. 106 Staff: Impika vs Inkjet cluster

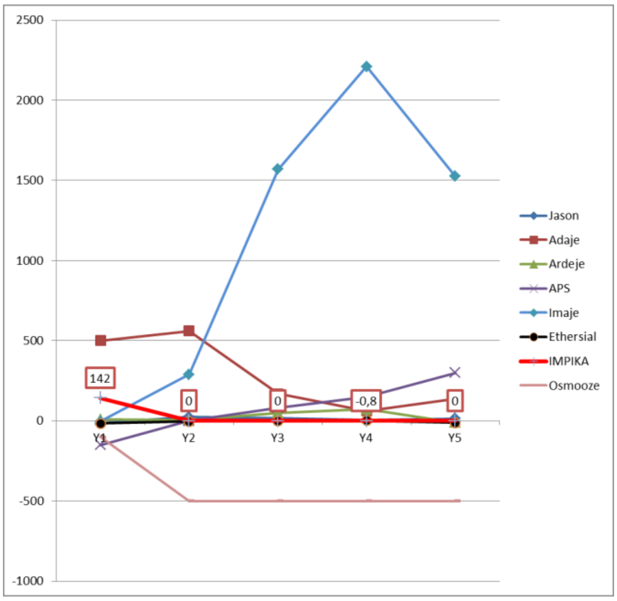


Fig. 107 EBITDA: Impika vs Inkjet cluster (K€)

Again, for this kind of very reputed startups, and as shown by the graphs and data above, there is a quite remarkable growth in turnover and staff.
But this strong growth is NOT nevertheless at the level of CIJ inkjet.
Besides, does the Impika's development refer to an exceptional value capture?

The answer is: NO

In any case, there is no outstanding recurrence to be seen.

Conclusion:
Outstanding growth in terms of turnover and staff evolution in the case of Impika; but poor EBITDA performance over the period → No exceptional value capture → No OP.

For such a company, the development over the first years after incorporation is enabled, not by the "intrinsic" exceptional value capture, but by recurrent investments from shareholders. It is then a question of business model.
So we have here an impressive growth in terms of turnover and staff level, but with No exceptional value capture. What leads to an incomplete OP.

Consider now again, a company within ***another sector than inkjet*** and regarded – according to expert judgement – also as an outlier in performance (OP): This firm is GEM+ S.A. (today Gemalto S.A.).

Does it match the synthetic criterion of exceptional value capture?

4.3.3 Case N° 3: GEMALTO / GEM+

Activity: Smart Cards manufacturer

Date of incorporation: 1988

Let us now look at the figures we gathered:

	1988	1989	1990	1991	1992
CA (Million €)	6.7	15.55	37.35	53	74.85
EBITDA (Million €)	>1	2.2	5.2[7]	6.6	8
EBIT Margin %	>16 %	14.1	13 .9	12.4	10.7
Staff	10	85	155	420	728

Table 32 - Historical data company GEMALTO

By considering 16%, we "normalize" the gross operating margin of the first year. For it included a reserve of orders ante establishment of the company (1 million smart cards for France Télécom/ Orange) what would distort calculations.

Quick analysis of OP on the basis of the Synthetic Criterion for Exceptional Value Capture and on 2 additional performance criteria:

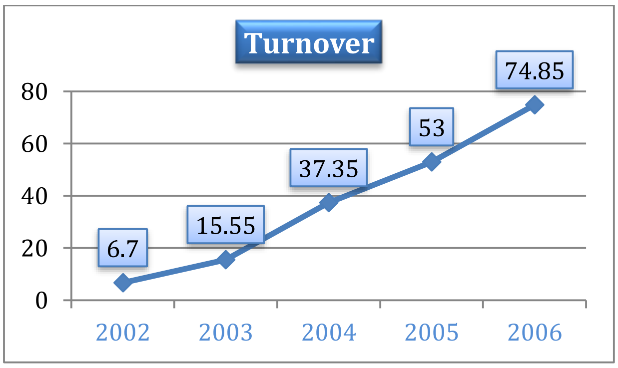


Fig. 108 Gemalto: Turnover evolution (million euros)

[7] 5 from a different source

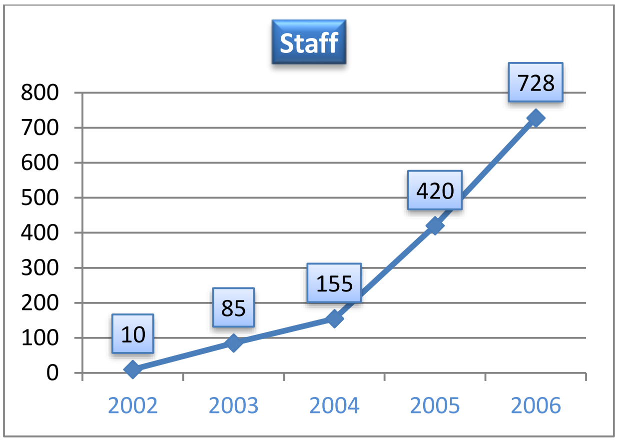


Fig. 109 Gemalto: Headcount evolution

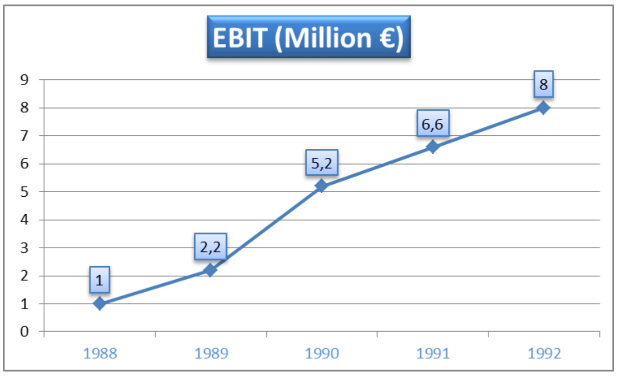


Fig. 110 Gemalto: EBITDA evolution

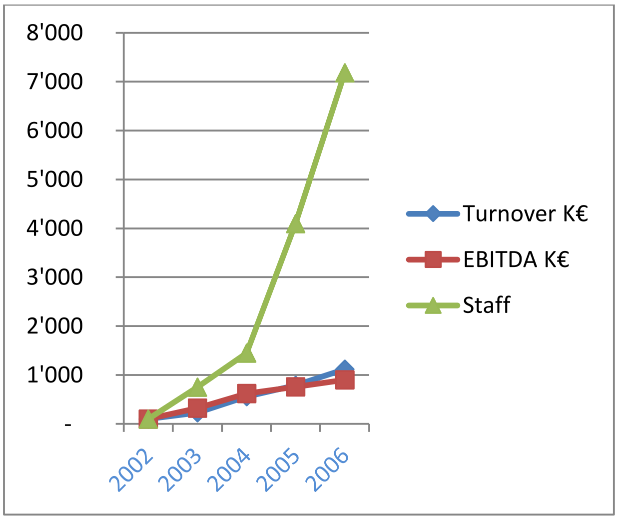


Fig. 111 Gemalto Synthetic Chart (index base 100 / year 1)

- Nota and Sources:

For most of the elements below references are coming from: JP Michon / Magellan 2013 / Smart cards EMV.

We have considered that the price of a smart card at origin was going from 10 to 20 FF (customization included).

The lifespan then was not exceeding 2 years in the banking sector. The cards were changed every year in reality.

To calculate the Gemplus recurring revenues for 2003 and before, we took an average of 7 FF per card. .

Therefore for 1 million cards sold in 2002 to France Télécom, the corresponding turnover was around 7 MF (source: Les Echos 1/25 /2005)

Besides and as far as the net margin on sales (for 1000 cards) is concerned, we stated:

- Reference Sales Price in euros: around 1.07 €
- Corresponding Net Margin per card: 1.07 x 13.42 % = 0.14 €

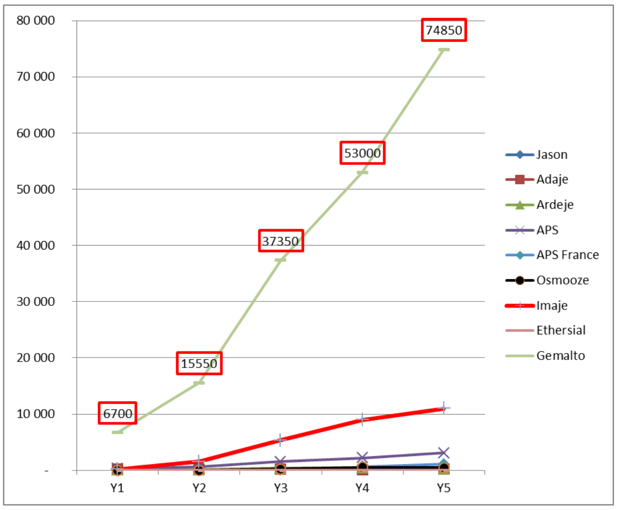


Fig. 112 Turnover: Gemalto vs Inkjet cluster (K€)

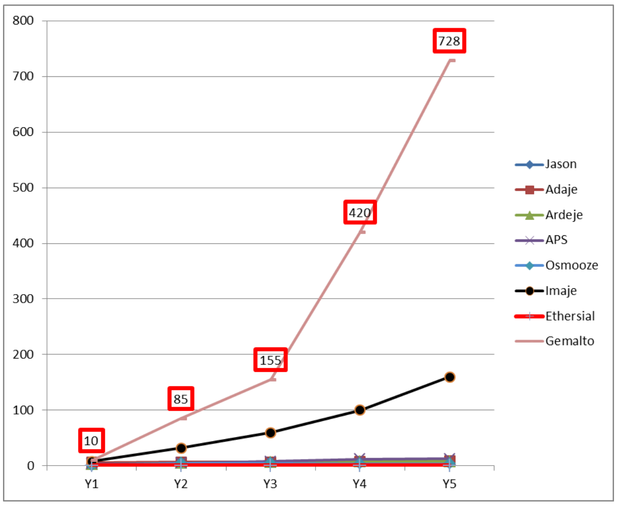


Fig. 113 Staff: Gemalto vs Inkjet cluster

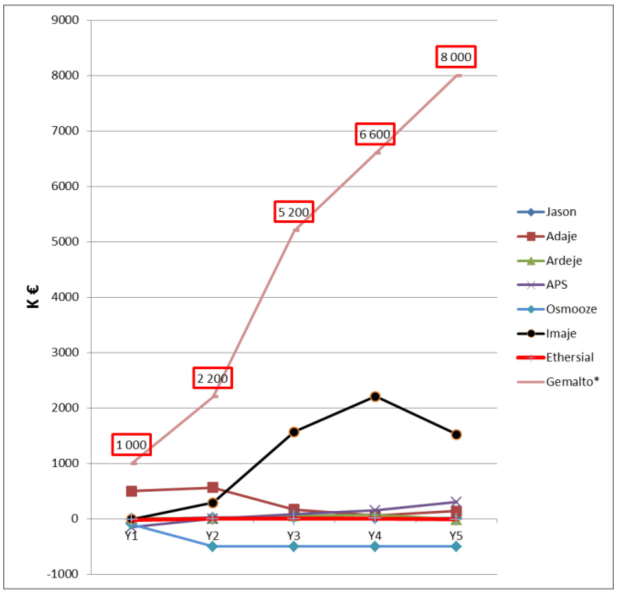


Fig. 114 EBITDA: Gemalto vs Inkjet cluster (K€)

Does the development of Gem+ (Gemalto) refer to an exceptional value capture?

The answer is clearly: Yes!

Additional comments about Gemalto evolution as a start-up and after the 5 first years:

- There is not only a question of % but of absolute values as well when considering the outstanding recurrence: After 2 years, the EBIT of Gemalto was superior to the turnover of Imaje S.A.!!

And all over the period considered (5 years) the EBIT in million euros of Gemalto was in the same order than again the turnover of Imaje!

- Conversely, over time, and after the 5 first years after the launching of the company, the value of the Synthetic Criterion of value capture was declining! Up to the point when it went to the minimum limit of noticeable performance (11%).

Was it the advanced signal for the difficulties faced by Gem + afterwards? That would deserve further research.

Other point: Does the development of Gem+ refer to an exceptional recurrence rate?

The answer is also: Yes.

Conclusion:

Outstanding growth in terms of turnover, staff level and exceptional EBITDA performance → Exceptional value capture → OP.

This supports and confirms the thesis.

4.3.4 Synthetic Board about Exceptional Value Capture

In this paragraph, we summarize the key set of information that we have used and generated.

Cumulative Re-Buy / Techs. Companies	Net Margin on Sales (K€) for 1 sale	Additional net margin (per year / K€) for 1 sale	Cumulative Additional Margin over 5 years for 1 device or product (K€)	Associated (Sales) Volumes ("Sales Unit")	Cumulative additional Margin x Volumes and Duration (over 5 years) Per "Sale Unit" In K€
CIJ SCP	**1,87**	**0,72**	**3,6**	**1 000**	**3 600**
Laser	**1,75**	**0,14**	**0,7**	**100**	**70**
Impika	**< 0**	**4,5**	**22,5**	**10**	**225**
Asconit[8]	**1,096**	**0,1**	**0,5**	**50**	**25**
Gemalto	**0,14**	**0,14**	**0,56**	**10 000**	**5 600**

Table 33 - Synthetic data on value capture

In accordance with what we have previously mentioned about explosive recurrence, the sales volumes of Imaje and Gemalto are to be considered not only as purely business- or sector related but also as a consequence of outstanding cumulative additional margins (exceptional cumulative re-buy).

[8] Asconit: calculations based on the average profit margin = 5.48 %

4.3.5 Comments and Future Research

Without adding to the very long roster of Technology Management concepts, and still broadly to Industrial Engineering; but while referring frequently to the theory of Disruption which we believe works and provides an efficient pattern, we would like to illustrate our discover and our modest tentative modelling in a quite pedagogical way.

Hence we will find strong similarities between key-elements in our approach and the symbiotic phenomena observed in life sciences.

The image of Symbiosis fits indeed many ideas developed in this dissertation: importance of value capture, importance of disruption, role of application as a concept…
In this sense, there is a symbiotic relationship between a given application and what we have called a "technological niche" corresponding to a specific know-how. This very symbiosis highly contributes and leads to exceptional value capture and super-performance.

So, if a *new actor* positions himself late in this "Symbiosis" scheme, the result will be: No Disruption (for the disruption was most likely already implemented by others).
But the performance is still there: Thus, when Linx (UK cluster) appears on the SCP market, it does not disrupt the existing solutions, but its performance is very good (Performance but No Disruption).

If Disruption happens, but without Symbiosis (emerging technology capturing less value on a recurring basis), the result is: Disruption but No Performance. Thus, when laser enters the coding market place, it delivers the same level of disruption than inkjet, but without performing so well.

Therefore, "Symbiosis" itself makes the performance, almost independently from the disruption level!
So, the technological solution must be cutting edge (very last generation of an efficient technological solution). But it does not need to be disruptive for outstanding performance.

What leaves a lot of room for research to come.

We also discussed the possibility to expand on these conclusions for other companies (Google, Nestlé/Nespresso …) and for other technical sectors; what we did for laser, smart cards (Gemalto), and even for services with the example of the company Asconit.

We made again a step along this path by considering the case of Amazon in this dissertation (see chapter 4).

When the subject further broadened, it turns in fact out that a lot of work remains to be done for identifying and characterizing OP in other sectors and fields than microfluidics.

So we leave it for future research to explain OP in trendy today cases like Apple, Nespresso (as already mentioned), Uber and others.

This will enable certainly to figure out other forms of exceptional recurrence and other levers for this recurrence, possibly different from the ones we discovered.

Chapter 5 - GENERAL CONCLUSION

5.1 Addendum

Beyond the conclusions drawn from our research on Spinoffs, Scientific Innovation, Microfluidics, Evolution theory and on Outstanding Performance, something should be add for politicians and decision makers on how to stimulate growth and wealth at the beginning of the 21st century.

When we see the number of companies (and hence jobs) created thanks to a single innovative anchor firm - and even without considering all the indirect jobs and activity generated – we can easily imagine the positive consequences in terms of economic development and Smart Specialization deriving from outliers in performance.

Indeed the conclusions of the present research indicate that an outstanding success can be related in the first place to a very specific combination Technology / Application ("bottom layer of technology"), and that a strategy only based on a "top layer of technology" (or GPT[9]) could be short to open way to such clusters' performances as the ones here described .

So indirectly we contribute to the idea that Smart Specialization (Infyde Europe, 2011) is a very favourable framework to develop new technology clusters.

Still more generally, we have to highlight the fact that the evolutionary question on which we worked was absolutely appropriate to my personal interest for the knowledge as a research topic by itself!
Working on an evolutionary prospective, even if related to a specific technological process like microfluidics, relates to working on other evolutionary processes: Plants evolve, animals are evolving too.
Working on evolution is thus mirroring some work in biology.
And the work on biological evolutions affecting trees and animals is also in turn possibly referring to human past and future.

And for sure, the science I like is a science connected to human life. When the knowledge is featuring a continuous improvement of one's humble mind.

5.2 Comments on Findings

- 1 major stake:

Some key issues in management are still related to measure! For example: How can we measure profitability?

How do you budget innovation when it is destroying short term profit?

About workcharts and metrics: what are the rules in a company that design this company?

And if each measurement (e.g. gross margin percentage) is referring to a ratio, there is still the need for a Theory to offer to managers how to measure. So much that in innovation, money is often lacking to go to adultery! In any case, moreover, innovation does not help to manufacture the figures managers are expecting (Christensen, 2012).

- 1 overall conclusion (kind of):

When <u>looking closer</u> to the context of events, problems or more specifically to outstanding growth, new forms of logic appear.

---

[9] General Purpose Technology

It is what we have shown at 3 different levels:

1- At the technological level.

2- At the level of the relationship between clusters.

3- At the level of the performance perceived mostly in the French cluster.

1- At the technological level, we showed that the evolutions in microfluidics were not as linear as the usual presentations would suggest.
The generalizability of this kind of findings to technological evolutions as a whole seems quite possible.

That would let of course some room for potential outliers!

Finding 1: In microfluidics, the technological evolutions are not linear.

2- At the level of the 2 clusters in microfluidics, commonly regarded as independent, we shown that in reality they had a common root in history, and that they were linked from their beginning.

They were associated not only by historical links but also through scientific knowledge and technical relationships as far as the fluids jetting systems were concerned.

Finding 2: The 2 European clusters were not independent in their development. They are epistemologically dependent in terms of general scientific knowledge and in terms of technology evolution.

3- At the level of the French inkjet cluster, we shown that the cluster's success reflected in companies performing above the SMEs average.

But we secondly stated that this overall result masked massive variations between firms.

That led us to emphasize the exceptional weight of the parent company in the cluster's results. What we translated into the concept of Outstanding Performance.

Finding 3: The parent company impacts exceptionally the cluster's overall performance. This indicates an Outstanding Performance.

Finding 4: A fractal approach of technological innovations reveals their complexity. To conclude efficiently, consideration must be given to the appropriate layer among the technological strata.

Finding 5: The 19th century was a century of emergence and triumph for the statistics.
The 20th century was the century of emergence for relativity (from our standpoint at scientific level, but also when generally speaking).
*The 21st century could be the century of triumph for **inductive methods** and **outliers** ("orphan" diseases, gender theory, allergies (cf. circumstance propitious to the disease in a specific body at a specific moment), black swan events, protected species, mutations…).*
In other words: The heydays of research about exceptional and unexpected value of a particular variable. One that changes radically the generally accepted representation of a phenomenon and hence the "mondaine représentation" (under the meaning of Johan Huyzenga and Roger Caillois) associated.

This is a matter of an exceptional value for a peculiar variable, or for a rare event.

We were committed to demonstrate that we should permanently avoid mere "immaculate statistical procedures sealed off from the real world" (Nate Silver, 2012). We had then **to look closer** to some data that can easily be mistaken for informational "noise" when they are potentially real signals.

For looking closer, one should never be satisfied with the use (or re-use) of secondary data.

Deep understanding implies most of the time *a direct connection with the reality*: Thus the discovery (in 2014) of 2 new stars by two high school students from Pontarlier directly observing a piece of sky!

2 stars that the most powerful telescopes, even if monitored by brand new generation computers and operating continuously did not manage to spot!!! (Académie de Besançon, May 26, 2014).
Let's not forget though, the so-called hidden variable (role of chance)!!! Meaning that it is not by merely gathering thousands of observers examining intensively a piece of the sky that one can discover new stars!

As we mentioned it earlier in the text, we will encourage and promote further research to broaden the outlook offered by cases about extreme values in performance as far as management of technology and technological innovation are concerned.
In this sense, iconic worldwide successes like the I-Phone or Nestlé's Nespresso would offer a very rich field to apply, test and complete our methodology in the light of all the large literature already existing on the reasons for explaining their extraordinary positive market results.
One purpose would be to figure out other forms of exceptional recurrence and other levers for this recurrence different from the ones we brought out.

Additional research could also question the period of 5 years that we choose to make outstanding performance appear and to qualify outliers.
If there is no consensus about the period that such work should cover, we tend to consider that 5 years is at the same time demanding enough and relevant:
Relevant for we have observed that surveys on longer period (Courault, Perez and Teyssier, 2011) are failing to get steady results.
And demanding enough; for we have shown, above in this dissertation that adding or changing a single year in the timespan covered would lead to consider more hyper growth companies. By the way, outstanding performance would become more common and outliers less exceptional!

5.3 Mathematical background.

All along this thesis, we built upon the fact that outliers are not just statistical aberrations. And we have brought forward more material to understand what extreme and rare events could mean.
For we were not satisfied with the traditional answers to the question about the status of extreme values and by the theoretical prospects considering them as some unnecessary data.
Statistically speaking, common analysis models are just ignoring extreme values.
If we disagreed with this consideration, it was mostly because of epistemological reasons: We had indeed the intuition that nonlinear behaviour in fluid dynamics could mirror some kinds of performance in industry.

We had understood that predictors of performance were persistently based on numerous variables and large statistic samples (i.e. bell curves everywhere).
And we concluded that outliers understanding was biased by the permanent use of secondary data, the mere duplication of data and quantifications (samples) that were not homogeneous.

If we take some distance from these ideas and try to bring to light a more global picture, we could consider the mathematical background of such a work the following way:
If the 20th century was the heyday for statistics related to belle curves and linear evolutions, the 21st century could be the century of triumph for maths and concepts applied to disruption and outliers, "orphan" diseases, black swan events, protected species, allergies …

In the case of extreme values, the best tool is not indeed a Gaussian approach! So we have to look closer to the reality were slight variations can lead to huge differences. Such an extreme sensitivity to initial conditions reflects a chaotic process fitting well with outliers. And fitting well with fluid dynamics also! For the reasoning applying to both are the same.
For the same kind of uncertainty impacts the Navier-Stokes equations, leading to the "explosion of solutions" described by Yakov Sinaï, and the performance of hyper growth high-tech companies.

2 dynamic systems relying then on the same theories.
What the PhD Dissertation tittle is suggesting without having anticipated it.

In fact, we intend to include our work into the evolutionary stream of the theory in statistics.
It started from Bernouilly to Lyapounov with the grounding pillars of statistical science: Namely the law of Large Numbers, the Central Limit theorem and culminating with the Gaussian distribution.

All this tooling enables to efficiently study **a large number of small independent contributions**.

Then came, from Pareto to Paul Lévy, other statistical pillars with the Lévy Alpha-stable distribution, the uneven distributions and the Cauchy process.

Such methods are to be used, in replacement of the previous ones, when **the standard deviation of each term is not neglectible any more compared to the standard deviation of the sum!** I.e. when extreme or rare events are dominating.

Nowadays, more and more attention is brought to updated statistical tools associated with "Black Swan" events. They refer to - from Grumbel to Mandelbrot -Extreme Values theory and Wild Chance.
They aim at **understanding first the nature of a specific random variable and its interdependent components** (hence stress tests…).

We leave to future work additional contributions to overcome the frustrating concept of chaos! We also expect with enthusiasm contributions to come on random systems and infinite dimensional systems. We are then on the border line between chaos and order. Such systems are, per se, extremely difficult; but extremely stimulating as well. They are anyway booming fields of research.

So we give tribute to primacy of variations within complex systems, for it enables to stick more accurately to reality.

Our conclusions are thus coming far from immaculate statistical procedures sealed off from the real world.

In applied sciences (does a non-applicative science exist?), the kind of connection with the reality that we promote is not severable from in detail understanding.
In other words, this understanding implies to ground one's analysis on ***techne*** (crafts and know how) and not on ***episteme*** (book knowledge, know what) only.

We hope that our work will be contributing, even if very slightly, to the daily existence of this view of science and knowledge.

BIBLIOGRAPHY

A

Afuah and Tucci, C. L. (2003). *Internet Business Models and Strategies (2nd ed.).* Mc Graw-Hill, New York.

American Printer (2006). I.T. Strategies predict $58bn inkjet printer market by 2009. *American Printer*.

Ancona D. and Caldwell D. (1992). Demography and Design: Predictors of New Product Team Performance. *Organization Science* Volume 3, issue 3.

Annual report (2010). *Products Review*. Etira.

Ansoff, I. (1965). *Corporate Strategy*. McGraw-Hill. New York.

Ansoff, I. and Stewart J. (1967). Strategies for a technology-based business. *HBR* pp. 77–83.

Audricourt, A.G. (1987). *La Technologie Science Humaine*. Fondation de la Maison des Sciences de l'Homme. Paris.

B

Banque de France (2011). Le financement des PME en France, *Stat info*, septembre 2011: http://www.banque-france.fr.

Banque de France (2009). Comptes consolidés des groupes:
La marge opérationnelle se dégrade. *Bulletin Banque de France* N° 178.

Banque de France (1997). Jacques-Bernard Sauner-Leroy**,** Stratégie et Formation de la Rentabilité des PMI*. Bulletin Banque de France* N° 39, mars 1997.

Barney, J. (1997). *Gaining and Sustaining Competitive Advantage*. Addison-Wesley.

Berg, B. (2004). *Qualitative research methods*. Boston: Pearson Publishing, 5th edition; chapter 10 "Case studies", pp. 251-264.

Birley, S. & Westhead, P. (1990). Growth and performance contrasts between "types" of small firms. *Strategic Management Journal*, vol. 11, Issue 7, pages 535–557.

Birley, S. & Westhead, P. (1994). A taxonomy of business start-up reasons and their impact on firm growth size. *Journal of Business Venturing, vol. 9, issue 1, pages 7-31.*

Bohm, D. (1952). A Suggested Interpretation of the Quantum Theory in Terms of "Hidden" Variables**.** *Physical Review 85,* 166 (15 January 1952)*.* New Jersey: Palmer Physical Laboratory, Princeton University.

Brun, M., Cayssials, J.L. & Kremp, E. (2011). Les PME-ETI cotées en bourse : la crise accentue les disparités et souligne les différences de réactivité. *Bulletin de la Banque de France* n° 184. http://www.banque-france.fr.

Brewer, C. (2010). Can Brother, Canon and Epson Successfully offer Business inkjet? *Recharger Magazine*, December 2010.

Brown, Shona L. and Eisenhardt Kathleen M. (1998). *Competing on the Edge: Strategy as Structured Chaos*. Boston: Harvard Business School Press.

Buchanan, D. & A. Bryman (eds.) (2009*).* Ethnography in organizational settings, chapter 35, pp. 602-619 (reading No.22). *Organizational research methods*. London: Sage.

C

Caillois, Roger (1958). *Les Jeux et les Hommes*. Gallimard : Paris.

Callon, Michel (1986). Éléments pour une sociologie de la traduction : la domestication des coquilles Saint-Jacques et des marins-pêcheurs dans la baie de Saint-Brieuc. *L'Année Sociologique* 36: 169-208.

Callon, Michel (2007). *What does it mean to say that economics is performative* ? In Donald MacKenzie, Fabian Muniesa and Lucia Siu (dir.). *Do economists make markets ? On the performativity of economics* pp. 311- 357. Princeton: Princeton University Press.

Calisti, B., Tucci C., Wieser P. (2014). Outliers and Russian Dolls! Hidden Drivers of Hyper Growth*. IMP Journal.* IMP Group.

Capon N., Glazer R. (1987). Marketing and Technology: A Strategic Coalignment*. Journal of Marketing* Vol. 51, pp.1-14.

Casanueva Cristobal, Castro Ignacio, José Galan (2011). Informational networks and innovation in mature industrial clusters. *Journal of Business Research*.

Cassia L., T. Minola T. (2012). Hyper growth of SMEs: Toward a reconciliation of entrepreneurial orientation and strategic resources. *International Journal of Entrepreneurial Behaviour & Research,* Vol. 18 Iss: 2, pp.179 - 197

Cayssials, J.L., Mangin, C. & Rakotoarivelo, J. (2011).
La situation financière au 30 juin 2011 des 70 premiers groupes industriels et commerciaux cotés en France reste solide. *Bulletin de la Banque de France* n° 186. http://www.banque-france.fr.

Cayssials, J.L. & Servant, F. (2011). En 2010, les PME bénéficient de la reprise mais diffèrent leurs investissements. *Bulletin de la Banque de France n° 185.* http://www.banque-france.fr.

Chai, F. & Nguyen, B. (2011). Le coût du crédit aux entreprises selon leur catégorie. *Bulletin de la Banque de France n° 185.*
http://www.banque-france.fr.

Christensen, Clayton (1997). *The Innovator's Dilemma*, Harvard Business School Press: Boston.

Christensen, Clayton and Raynor, Michael (2003). *The Innovator's Solution*. Harvard Business School Press: Boston.

Christensen, Clayton (2006). The Ongoing Process of Building a Theory of Disruption. *Journal of Product Innovation Management.*

Cialdini, R. (1987). *Influence*. Albin Michel: Paris.

Clinvest Report (1995). *Memorandum F013*, January 1995.

Clymer and Asaba, S. (2008). A new approach for understanding dominant design: The Case of ink-jet printer. *Journal of Engineering Technology Management,* 25: 137-156.

Colletaz, G. and Hurlin, C. (2006). *Modèles non linéaires et Prévisions*. Institut CDC pour la Recherche – CNRS.

Cooper, A.C. (1993). Challenges in predicting new firm performance. *Advances in Entrepreneurship*, vol. 2. Westhead, M. Twight & E.Elgar Publishing.

Cooper, A.C., Javier Gimeno-Gascon, F., Woo, C.Y. (1994). Initial human and financial capital as predictors of new venture performance. *Journal of Business Venturing 9, 371-395.* Elsevier Science : New York.

Courault J., Perez M., Teyssier C. (2011). *Hyper growth in SMEs: from hyper performance to hyper fragility*. WP Coactis: Lyon.

Cresswell, C. and Ghazaeepour, M. (2011). *Western Europe Supplies Market Trends*. Infotrends.

D

Davidsson, P. (1991). Continued Entrepreneurship: ability, need, and opportunity as determinants of small firm growth. *Journal of Business Venturing.*

Dickson, T. (1983). Small Business: How Domino spotted that products alone were not enough. *Financial Times* 11 January 1983.

Direction générale du Trésor (2011). Le taux de taxation implicite des bénéfices en France. *Trésor-éco* 88, juin 2011. http://www.tresor.bercy.gouv.fr/TRESOR_ECO/ francais/pdf/2011-006-88.pdf.

Direction générale du Trésor (2011). Comment expliquer la reprise de l'investissement en France malgré la faiblesse du taux d'utilisation des capacités de production ? *Trésor-éco* 90, juillet 2011. http://www.tresor.bercy.gouv.fr/TRESOR_ECO/francais/pdf/2011-009-90.pdf.

Domino Report (1991). Accounts, Highlights 1991 and Five Year History.

Dosi, G. (1982). Technological paradigms and technological trajectories: A suggested interpretation of the determinants and direction of technical change. *Research Policy* 2 (3).

Dosi, G. (1988). Sources, Procedures and Microeconomic Effects of Innovation. *Journal of Economic Litterature* vol. XXVI, 1120-1171.

Dyer, J. et al. (2011). The Innovator's DNA: Mastering the Five Skills of Disruptive Innovators. *Harvard Business Review Press.*

E

Economist (2002). Spitting image: case study on the inkjet printer. *The Economist* 19th September, 2002.

F

Folta T. B., Arnold C. Cooper, Yoon-suk Baik (2006). Geographic cluster size and firm performance. *Journal of Business Venturing* 21, 217–242.

Ford, S. and al. (2010). The Dynamics of Industrial Emergence, *PICMET'10 Conf.* 18-22 July 2010. Phuket: Thaïland.

Foucault, Michel (1966). *L'Archéologie du Savoir*. Gallimard : Paris.

Franco, A. M. and Filson, D. (2006). Spin-offs : Knowledge Diffusion through Employee Mobility. *37 RAND Journal of Economics* 841 - 60.

Freeman, R.E. (2010). *Strategic management: A stakeholder approach*. Cambridge University Press: Cambridge.

G

Garnsey E., Heffernan P. (2005). 'High Tech Clustering through Spin Out and Attraction; the Cambridge Case', *Regional Studies* Vol. 39.8, pp. 1127-1144, November 2005.

Garnsey et al. (2009). *The Emergence and Development of the Cambridge Ink Jet Printing Industry*. IFM – University of Cambridge.

Garrett (1985). Domino Printing Offer To Raise 11 Million Pounds. *Financial Times* 19th April 1983, p20.

Ghoshal, S. (2005). *Bad Management Theories are Destroying Good Management Practices*. Academy of Management Learning and Education, 2005 Vol. 4 Nb. 1, 75-91.

Gibbert, M. and Hoegl, M. (2011). That's not our business or is it? In praise of dissimilarity. *MIT Sloan Management Review* 52 (4): 20-22.

Giraud, P. (2012). *Ink-jet Science*. Pagora Conference, Spring 2012.

Gladwell, M. (2000). *The Tipping Point.* Little, Brown and Company: Boston

Gladwell, M. (2008). *Outliers.* Little, Brown and Company: Boston

Gould, Stephen (1996). *The Full House*. Harmony Books: New York.

Graillot, L. (1998). Emotions et comportement du consommateur. *Recherche et Applications en Marketing* 13, 1, pp.5-25.

H

Haber, S. and Reichel, A. (2005). In *Journal of Small Business Management* , July 2005, 43.3 pages 257-286.

Hall, G. & Fullshaw, S. (1993). *Article Factor associated with relative performance amongst small firms in the British instrumentation sector*. Entrepreneurship and Business Development, H.Klandt.

Haudricourt, André-Georges, and Dibie, Pascal (1987). *Les Pieds Sur Terre*. Métailié : Paris.

Heeley, M. B. and Jacobson, R. (2008). The recency of technological inputs and financial performance. *Strategic Management Journal* volume 29, Issue 7 July 2008, pages 723–74.

Hmielski, K. M. & Corbett, A. C. (2008). The contrasting interaction effects of improvisational behaviour with entrepreneurial self-efficacy on new venture performance and entrepreneur work satisfaction. *Journal of Business Venturing*. New York: Jul 2008. Vol. 23, Iss. 4; pg. 482.

Huizinga, J. (1951). *Homo Ludens*. Gallimard: Paris.

I

IDC (2011). Market shipments year over year. *Worlwide Quarterly Hardcopy Peripherals Tracker* March 2011.

Imaging Industry (May 2011). Available from: http://www.therecycler.com.cn/en/ap/zhuhai-printer-consumables/zhuhai-supplement.asp. [Online].

Del Castillo J., Barroeta B., Paton J. (2011). *Converting Smart Specialisation into a Regional Strategy*, Información y Desarrollo. Infyde Europe Working Paper.

Insee (2011). La reprise se grippe. *Point de conjoncture* octobre 2011. http://www.insee.fr/fr/indicateurs/analys_conj/ archives/octobre2011_ve.pdf.

Insee (2011). Les investissements dans l'industrie. *Enquête 2011*. http://www.insee.fr/indicateurs ind. 15/20111109/investissement_102011.pdf

Insee (2011). L'économie française 2010-2011. *Insee références* Juin 2011.

Insee (2011). En 2010, la moitié des PME d'au moins dix personnes ont recherché un financement. *Insee Première* 1379, novembre 2011 http://www.insee.fr/fr/ffc/ ipweb/ip1379/ip1379.pdf.

IT Strategies (2008). *Worldwide Digital Printing Market Report*. IMI.

K

Kahneman, D. (2011). *Thinking Fast and Slow*. Doubleday: Can.

Kahneman, Daniel (2012). *Système 1/ Système 2 : les 2 vitesses de la pensée*. Flammarion.

Kano, Noriaki; Nobuhiku Seraku; Fumio Takahashi & Shinichi Tsuji (April 1984). *Attractive quality and must-be quality. Journal of the Japanese Society for Quality Control* (in Japanese) 14 (2): 39–48.

Kaverman, John (January-February 2004). *Innovative Marking Systems*. Plastics Decorating.com.

Keating, P. and A. Cambrosio (1994). Ours is an engineering approach: Flow Cytometry and the constitution of human T-Cells. *Journal of History of Biology* 27(3): 449-479.

King, Andrew & Tucci, Christopher (2002). Incumbent Entry into New Market Niches: The Role of Experience and Managerial Choice in the Creation of Dynamic Capabilities. *Management Science.*

Klepper, S. (2001). Employees Startups in High-Tech Industries. *Industrial and Corporate Change*, vol.10 Nb. 3.

Klepper, S. (2007). Disagreements, Spinoffs and the Evolution of Detroit as the capital of the US Automobile Industry. *Management Science 53: 616-631.*

Kollewe, J and G. Wearden (2007). ICI: From Perspex to paints. *The Guardian* 18th June 2007.

KPMG survey (2007). *Restructuring in SMEs : France*. Survey Report.

Kremp, E. & Servant, F. (2011). Les délais de paiement en 2010: l'effort entrepris depuis la mise en oeuvre de la LME marque le pas. *Bulletin de la Banque de France* n° 186. http://www.banque-france.fr.

L

Latour, B. (1984). *Les microbes : guerre et paix*. Paris : Métailié.

Latour, B. (1995). *La science en action : introduction à la sociologie des sciences*. Paris : Gallimard.

Latour , B. (2006). *Changer de société. Refaire de la sociologie.* La Découverte : Paris.

Le, H. P. (1998). Progress and trends in inkjet printing technology. *Journal of Imaging Science and Technology* 42: 49-62.

Leconte, C. (2011). *Inkjet Inside: Market trends, challenges and attitudes*. Lyra.

Loren, G. and Kantor, J.M. (2009). *Naming Infinity*. Harvard University Press.

Les Echos (2013). Une entreprise sur 2 passe le cap des 5 ans*. Les Echos Entrepreneur* 12 April.

Low, M. B. and MacMillan, I. C. (1988). Entrepreneurship: Past Research and Future Challenges. *Journal of Management* 14: pages 139-161.

M

Management Today (1992). Domino jets ahead. *Management Today.*

Mandelbroot B. (1997). *Fractals and Scaling in Finance: Discontinuity, Concentration, Risk*. Springer.

Médiation du crédit aux entreprises (2011). Report octobre 2011. http://www.mediateurducredit.fr/site/content/download/465/2764/file/RAMDC2011.pdf.

Michel, Naudé, Salle and Valla, (2003) *Business-to-Business Marketing*. Palgrave Macmillan.

Miller, A. (1988) A taxonomy of technological settings, with related strategies and performance levels. *Strategic Management Journal* Volume 9, Issue 3, pages 239–254, May/June 1988.

N

Nelson, R. and Winter, S. (1982). *An evolutionary theory of economic change*. Harvard University Press: Cambridge, MA.

Nelson, R. H. (2001) *Economics as Religion*. PA: The Pennsylvania State University.

O

Observatoire des délais de paiement (2011). *Une réforme en voie de succès, des zones d'ombre à explorer*. Rapport Avril 2011. http://www.banque-france.fr.

Observatoire du financement des entreprises (2011). *Le financement des PME-PMI et ETI en France.* Rapport Avril 2011. http://www.mediateurducredit.fr/site/content/ download/444/2637/file/RapportObsfi %20.

Owen-Smith and WW Powell (2004). *Accounting for Emergence and novelty in Boston and Bay Area Biotechnology. Cluster Genesis: The emergence of technology clusters and their implication for government policy*. Ed. P. Braunerhjelm and M. Feldman, 61-83. Oxford University Press

P

Pascal B. (1897). *Les Pensées*. Léon Brunschvicg editor: Paris.

Peters E. (1996). *Chaos and order in the Capital Markets*. Wiley.

Pira international (2010). *The future of inkjet printing to 2015* pp. 10-99. Pira.

Popper, K. R. (1968). *The Logic of Scientific Discovery*. New York: Harper and Row.

Products Review (2010). Large format printers. Available from: http://www.usa.canon.com / cusa /office /products /hardware large_format printers 2010.

R

Rayleigh, F.R.S. (1878). On the instability of jets. *Proc. Lond. Math. Soc* .10 (4), 4-13

The Recycling Times Magazine (2011). *Print Pack* p.16, May 2011. Recycling Times Media Corp.

Remanufacturing and Product Design (2010). available from: http:// www.remanufacturing.org.uk.

Reynolds, P.D. (1993). *High performance entrepreneurship: What makes it different?* 13 th Babson Entrepreneurship Research Conference.

Rhyming, Inge L. (1957, réimpr. 1985, 1991). *Dynamique des fluides*. Presses polytechniques romandes Chapitre 6.

Ries, E. (2011). *The lean startup: How today's entrepreneurs use continuous innovation to create radically successful businesses*. Crown Books.

Robinson, A. G. and S. Stern (1997). *Corporate Creativity: How Innovation and Improvement Actually Happen*. Berrett-Koehler. San Francisco

S

Schwartzman, H. (1993). *Ethnography in organizations*. Sage. London.

Sitkin Sim B., See Kelly E., Miller Chet C., Lawless Michael W., Carton Andrew M. (2012). *The Paradox of Stretch Goals: Organizations in Pursuit of the Seemingly Impossible*. AOM 2012.

Silver N. (2012). *The Signal and the Noise.* Penguin Books: London

Sirelli, G. (2000). Innovation and firm performance, summary of session C. *Conference innovation and enterprise creation: Statistics and indicators*. France, 23-24/11/2000.

Slembrouk (2007). *Challenges for inkjet printing in packaging*. *Packaging Technology: Fundamentals, Materials and Processes*. Anne & Harry Emblem Ed.

Sloan, Alfred P. (1964). *My Years with General Motors*. Republished in 1990 with a new introduction by Peter Drucker. McDonald, John. Doubleday Garden City. NY, USA.

Start R., and Abetti, P.A. (1987). Start-up venture: towards the prediction of initial success. *Journal of Business Venturing* 2(3): 215-230.

Sweet, R.G. (1965). High frequency recording with electrostatically deflected ink-jets. *Rev. Sci Instrum. 36, 131.*

T

Taleb, N. (2012). *Anti Fragile*. Allen Lane: U.K.

Tang, H. K., W. H. Kuek, et al. (2000). *Inkjet printer pioneers and competitors*. IEEE Spectrum 2: 94-101.

Teece, David J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research Policy* 15 (6): 285-305.

Tetlock, P.E. (2005). *Expert Political Judgment: How Good is it? How Can we Know?* Princeton University Press, p 54.

Thompson, J. (2009). *Funding Breakthrough Technology: Ink jet printing case report.* CBR report. Cambridge.

Tonge, R., Larsen, P. and Ito, M. (1998). Strategic leadership in super-growth companies - a re-appraisal. *Long Range Planning* 31 (6). pp. 838-847.

Tucci C., Seifert R., Leleux B. (2008). *Nurturing Science-based Ventures.* Springer: England.

Tsoukas Haridimos and Hatch Mary Jo (2001). *Human relations: Complex thinking complex Practice* . Sage.

Tushman, M. & O'Reilly, C. (1996). Ambidextrous organizations: Managing evolutionary and revolutionary. *California Management Review* 38(4): 8–30.

Tushman, M. & O'Reilly, C. (2004). The ambidextrous organization. *Harvard Business Review,* 82(4): 74–81.

V

Vesper, K. H. (1980). *New Venture Strategies*. Prentice Hall. Englewood Cliffs.

Von Hippel and al. (2008). Pyramiding: Efficient identification of rare subjects. *MIT Sloan School of Management Working Paper* 4719, 08 October, 2008.

W

Wasserman, S. and Faust, K. (1994). *Social Network Analysis: Methods and Applications*. Cambridge University Press: Cambridge.

Wieser, P. (2013). *Essentials of Logistics and Management*. 3rd Ed. EPFL Press: Lausanne.

Www.ac-besancon.fr › Académie › Actualités › Vie de l'académie (May 26, 2014): le club d'astronomie du lycée Xavier-Marmier à l'honneur.

Www.argosinvest.com (2013). *Argos Mid-Market* Tuesday, May 14th.

X

Xerfi (2011). *Marché des imprimantes et photocopieurs*. January 2011. Xerfi.

Xerfi (2015). *Machines for the printing industry.* October 2015. Xerfi.

Y

Year in Review (2010). OEM are remanufacturers. They embrace "The more the Better" Principle in the Inkjet supplies market. *Lyra* February 2011.

Yin, R. (2003). *Case study research. Design and methods*. 3rd edition; chapter 2 Designing cases studies, pp. 19-56; chapter 4 Conducting case studies: collecting the evidence, pp. 83-108; chapter 6 Reporting case studies, pp.141-169. Sage: London.

APPENDIX 1 - Companies in the panels and interviewees

Names of SPINOFFS from IMAJE S.A. and the French ink jet cluster.

Company	Location
APS	Valence (France)
Jason	Valence (France)
Ardeje	Valence (France)
Adaje	Valence (France)
Timis	Valence (France)
Marquage Product	Valence (France)
Codeco	Valence (France)
AOMS	Not based near Valence
Osmooze	Valence (France)
Dracula Tech.	Valence (France)
Ciamtech (Tiflex)	Valence (France)
Teampack (APS)	Valence (France)
Amici	Valence (France)
Impuls	Valence (France)
Ethersial	Valence (France)
Emblème	Valence (France)
Impika	Not based near Valence (Aubagne)
Siliflow	Valence (France)
Codesys	Valence (France)

Names of SPINOFFS from CCL and the British ink jet cluster.

Company	Location
Domino	Cambridge (England)
Biodot	Cambridge (England)
Inski	Cambridge (England)
Xennia	Cambridge (England)
Willett	Cambridge (England)
Linx	Cambridge (England)
Elmjet	Cambridge (England)
Xaar	Cambridge (England)
Inca	Cambridge (England)
Imaje	Cambridge (England)

Interviewees

Name	Position	Founder	Company
DAMIRON Jacques	General Manager	YES	ADAJE
SANTONI Christian	General Manager	YES	JASON
BAJEUX Paul	Director	YES	ETHERSIAL
PIERRON Pascal	General Manager	YES	ARDEJE
DOREZ Michel	General Manager	YES	OSMOOZE
FERBO Xavier	General Manager	YES	APS
DURAND Jacques	Director	NO	IMAJE
GALAN Jean	R&D V.P.	NO	IMAJE
MARFAING Paul	Accountant	NO	AMICI
MUNIER Yves	Manager	YES	SILIFLOW
RODRIGUES Francis	General Manager	NO	IMPULS
NOLL Fred	President	YES	MAIN STREAM LLC

APPENDIX 2 - Interview protocol

Semi-structured interview

Introduction: **(5 minutes)**

Introductions. Thank you for taking the time to meet with us. We know how busy you are and appreciate your willingness to discuss your experience in spin-offs' performance with us.

As set out in our research statement, we are interested in better understanding how spin-offs from the same parent are evolving and what dynamics underpin the performance of the successful ones.

We are conducting a survey in the field of micro-fluidics and analyzing the clusters for ink jet in France, England and US.

This interview consists of general questions about your spin off experience, particularly in terms of growth and technology choices, the relationships, if any, with the parent company, and specific questions about what have influenced the evolution of your activities.

Before we begin, we would like to answer any questions you might have about the purpose of this interview and reassure you about how the information will be used. We guarantee complete confidentiality at the interview level. Nothing you say will ever be linked with your name in our research without your permission. Transcripts will only be available to the 3 primary researchers in the study (Profs PH. Wieser, Chris. Tucci and B. Calisti).

We'd like to tape record our conversation. This is mainly a way to take notes and ensure accuracy - I find it hard to both carry on an interesting conversation and take notes at the same time. Of course, you are free to ask that the tape be turned off at any point during the interview. [*If still uncomfortable, offer the review of transcripts.*]

Do you have any questions before we get started?

***Subject's Background:* (5 minutes) /10**

We'd like to start with some basic information, just to get a feel for your company and your role at XXX (e.g. Jason).

1. What is your official position in the company?

2. What is your background? (education – engineer or otherwise, where primarily worked within firm)

3. What brought you to found a company?

***General Company Trends in Development Policy:* (15 minutes) / 25**

We are primarily interested in Spinoffs' performance, but would like to get an overall picture of the scope of your project as an entrepreneur and your ambition for Jason first.

1. Can you briefly describe your business?
2. What was your ambition at origin?
3. Did you found Jason alone?
4. Did you intend mainly to create your job or an actual start-up? [individual spinoff vs structured spinoff]
5. *Probes :*
6. How many employees were working within the company when starting?
7. At date?
8. What were the competencies associated at origin (if any)?

***Reasons for Growth, Stagnation or Failure* (15 minutes) / 40**

1. How do you explain the evolution of the venture? [growth or no growth]
2. Did you expect more or less development / growth that you realized?
3. Was the launching favored by other persons and/or companies from the same cluster outside the company?
4. What were, according to you, the levers and pitfalls to the development of the company?
5. What can you say about :
    - Your technological differentiation?
    - Your technical choices?
6. How did your turnover evolved during the 5 first years of your company?

[*If performance is not good in comparison with parent company, just ask: Why??, if it is ask also why?]*

***Technology and performance* (10 minutes) / 50**

1. *Ask*: in your sector, in terms of technology: How do you measure the performance? (e.g. Dots per Inch or MTBF. …)
2. Did these criteria evolved over time? [*That will enable to define the "link" with the parent company in technological terms or the orientation towards "unrelated industries" . It will also enable to track the path followed by the companies on the continuum between "same industry" and "unrelated industry"]*

***Reasons for spinning off* (15 minutes) / 1h05**

Why did the founder left the parent company?

A series of reasons to explain spinoffs' launching are stated. Which one, if any, do you consider as relevant in your case?

Do you consider that the incumbent was:

- Not able to participate to such a project [the one grounding the spinoff]

1. (Agency theory): because of its cost structure ? i.e. the project couldn't be profitable in the framework of the parent company
2. (Organizational Capability Theories): because of organizational reasons ? i.e. the organization of the parent company and its dynamics was not in line with the needs of the project.

- Not aware of the project

3. (Employee Learning Theory): you didn't want the incumbent to be aware of such a project.

- Not willing to conduct the project but ready to help

4. (Heritage of Spinoffs Theories): The project was discussed and supported by the Parent Company

Can you mention a company in your cluster that was particularly successful?

Probes:

a) What factors, in your opinion, contributed to this success?
b) Similarly, can you give an example of a spinoff that was particularly unsuccessful?

c) Again, what factors do you think prevented this venture from being successful?
d) Do you consider this / some of these companies as "champion(s)" in the field of micro-fluidics?

What about spinoffs in the cluster that were less brilliant but nevertheless ventures that led to improve ink jet technology? Can you mention a name?

***Indirect and direct links with the Parent Company (Imaje):* (15 minutes) 1h20**

To give us a better understanding of how you started and developed, could you tell us about the links with the Parent Company? *[If some have already been mentioned, follow up on these ones...]*

……..

Probes:

a) Are you subcontracting for the parent company [check the importance and the regularity of this business]?
b) [Qualify the links more precisely] How would you qualify the nature of this link?

- Negative link with parent company?
- No link with parent company?
- Positive link with parent company?

c) [If relevant]: What is / was the purpose of the collaboration? How does it fit into the company's project? [use whatever terms have come up in describing the collaboration here]
d) Who was involved?
e) In the common work with the parent company you described above, did you have any concerns about negative impacts of this on Jason's competitive position?
f) What about the positive side of this collaboration?

Parent Company / Spinoffs' cooperations that we've seen elsewhere run the gamut from narrow, focused projects for immediate business results, to cooperations aimed at basic technology breakthroughs, sometimes even opening up entirely new areas for the company. Where would you place Imaje's various cooperations along this continuum?

To what extent would you say IMAJE uses spinoffs' cooperation just to "get the job done" versus actively learning about a new area of technology or operations?

***Indirect and direct links with other spinoffs from the same cluster* (10 minutes) / 1H30 [explain the idea of cluster: spinoffs from the same parent]**

We're particularly interested in the issues of knowledge and competences sharing in the cluster. For example...

We'd like to ask a few questions on the structure and nature of your partnerships within the cluster.

Do you have relationships with other spinoffs from the cluster (same parent)?

What kind of relationships? Common projects, HR migrations, friendship with other founders ….

Probes:

a) To what extent do you give preference to spinoffs from the cluster when forming a project?
b) Can you think of an example where you entered into a project with another spinoff from Imaje?
c) What were the main benefits / issues of this partnership?
d) Did you have access - through this kind of projects – to:

- New technologies?
- New competencies (direct knowledge)?
- New collaborators?

Final interesting question – if time: Events sampling

When did you first ship the product?

General Data (5 minutes)

Name of the company

Address

Tel number

Website address

Name (person)

Date of birth / age

E mail

Tel number

Position of the person:
Title
Function

Founder of the company

Date of the founding

Number of people

Number of jobs created (at a peak)

Turnover

Profit level: average / under average / above average

[To end the interview: Take a picture of the interviewee + gather other pictures of the activity.]

If time and interest…

Personnel performance assignment issues:

1) How do you assign personnel to performance?
   - *Probes*:
   a) Have your performance metrics evolved over time?
   b) What steps do you take to address your concerns?

2) For you, is the ability to hire "6 digit salaries" a criterion of performance?

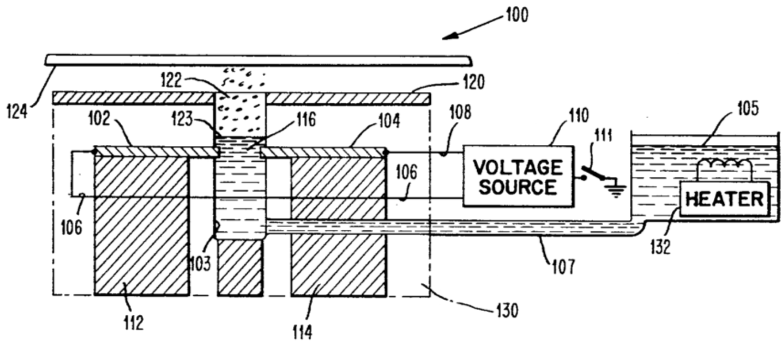
APPENDIX 3 - Using a Delphi method to complete the survey

As group facilitator we have selected a group of experts based on the topic being examined. Once all participants have been confirmed, a questionnaire was sent to each member of the group with the instructions to comment on each topic based on their personal opinion and experience. The questionnaires were returned to the facilitator for grouping the comments and to prepare a compilation of the information.

Then the synthesis was submitted to the comments of each expert, offering also the opportunity to comment further.

APPENDIX 4 - Technical notes and additional scientific and technical information

- Sudden Steam Printing: The first drop-on-demand thermal inkjet device (see early scheme below), was patented in 1965, but not developed into a commercial product.



- Detailed calculation (e.g.) on prices and margins for inkjet:

Sub. Tech.	DOD piezo	CIJ single nozzle	CIJ multiple nozzles
Assumptions	Equipment price > 50 K€ Gross Margin ≈ 50% Parts and service 2.3 K€ every 1.5 year Margin 60 % Fluids 2.8 K€ Margin 41 %	Equipment 12 K€ Gross Margin 68% Inks and parts and service 2.4 K€ every year Gross Margin 60 % on maintenance and 75 % on fluids	Equipment ≈ 50 K€ Margin 43 % Parts and service 3.66 K€ every year Gross Margin 69 % Fluids 5.081 K€ Gross Margin 86 %
Calculations	(2.3 x 0.6 x 2/3) + (2.8 x 0.4) = (0.92 + 1.15) = 2.07 K€	2.4 x 0.75 x 2/3) + (2.4 x 0.6 x 1/3) = 1.2 + 0.48 = 1.68 K€	(3.17x.69) + (5.08x.86) = 2.19 + 4.37 = 6.55 K€

- Addendum on the non linear nature of technical evolutions.

TIJ could be manufactured using mass-production processes based on IC manufacturing technologies.
This made the cost per nozzle much lower than the cost per nozzle of a pre-existing piezoelectric DOD printhead.

The fact that inkjet printers could then be miniaturized along with a low manufacturing cost, leaded to position TIJ as the reference inkjet technology.

For an SPT's printhead:

- The outlet diameter of the nozzle is 18 μm, when the ink chamber height is 18 μm.
- The nozzle pitch in a single row is 42. 3 μm and both nozzle rows are shifted a half nozzle pitch with respect to each other.

This results in a nozzle resolution of 1200 npi.

HP had solved the reliability problem associated previously with thermal drop on demand Printheads with its concept of *disposable heads*.
And the fact that HP kept increasing the performance of its thermal printheads continuously also explains its success.
Besides, HP claims that TIJ can jet everything that nucleates like toluene, silver suspensions, and even functional proteins.
Currently, thermal inkjet, with top-shooters from HP, Canon and Lexmark, and side-shooters from Canon (the first series) and Xerox, dominates the low-end SOHO (Small Office and Home) color printer market.

Océ also uses thermal drop-on-demand inkjet in its wide format color printing systems with printheads from various manufacturers.

After the introduction and broad acceptance of TIJ by the market, PIJ research efforts have largely diminished.

However, in TIJ, the spreading and inter-color bleeding of water based inks are constantly critical and often require special coatings on the media surface.

At high productivity levels, cockling and drying of the media can also be considered as issues.

Therefore, solid inks (hot-melt or phase-change inks), requiring piezo actuation represent sometimes preferred alternatives.

In 1984, new initiatives with a bump-mode design were taken by Howtek and Exxon, later acquired by Dataproducts.[1]
The shearmode design came into the field thanks to Spectra in 1984, (patents from Xerox), and later with Brother. Spectra was acquired by Markem, then by Dimatix and finally by FujiFilms.
A specific version of the shear mode is the shared wall variant designed by the British company Xaar.
This company started in 1990 for making real some ideas promoted by Cambridge researchers (English Cluster / see after).
Among other companies having used this concept Brother/Kodak, ToshibaTEC and MicroFab (US) are to be mentioned.

MicroFab is giving us an opportunity to illustrate the complexity of evolution for a technology like ink jet and the importance of very detailed knowledge to understand the success or failure of a specific application of this very technology.
MicroFab had indeed developed heads that would accept a temperature up to 180 °C. It was a very promising solution then to deposit drops of tin. But the early enthusiasm with these heads short-lived. For as the surfaces ("captons") were cold (25 °C), the droplets of tin were rolling over the substrate!

PIJ started with 12 nozzles in a single color glass chip in 1984. Via different printer series, this evolved into the 3900 nozzles in a six color single silicon chip in 2006, the Scalable Printhead Technology (SPT).

At present, TIJ and PIJ DOD printers both dominate the technology landscape when it comes to printing.

But the initial advantages of TIJ over PIJ have been leveled over the years by further development of the PIJ technology.

Moreover, a fundamental strength of the PIJ technology is its ability to deposit a wide variety of materials on various substrates in well-defined patterns.

Recently many other applications than printing onto paper have emerged.
In the display market, for example, inkjet technology is used to manufacture Flat Panel Displays (FDP), Liquid Crystal Displays (LCD), color filters (a part of LCDs), Polymer Light Emitting Diodes (PLED), and flexible displays.

The accompanying performance criteria are among the major driving forces behind much research and development efforts.

Within the chemical market, the inkjet technology is mainly used as tool for research purposes. The unique capacity of the technology in dispensing small doses of liquids makes it very useful for this market.
Applications include material and substrate developments as well as coating purposes.
In the electronic market, inkjet printheads are used to create functional electrical tracks using conductive fluids on both rigid and flexible substrates.

One of the first applications of inkjet technology within this field was that for the production of Printed Circuit Boards (PCB).

Other applications include the fabrication of electric components and circuits such as Radio Frequency Identification (RFID) tags, wearable electronics, solar cells, fuel cells, and batteries.

Challenges for the inkjet technology within this field include the ink absorption and the required guarantees of continuity of the jetted lines.

Three-dimensional mechanical printing claims the inkjet technology as tool for rapid prototyping, small volume production, and the production of small sensors. Jetting of UV-curable optical polymers is a key technology for the cost-effective production of micro-lenses.
These tiny lenses are used in devices from fiber optic collimators to medical systems.
The ability of inkjet technology to precisely jet spheres in variable, but consistent, drop size, provides opportunities for the cost reduction of existing optical components and innovative new designs.

The life science market is rapidly expanding with new requirements for accurate dispensing of DNA and protein substances.
The high cost of these fluids makes inkjet technology with its precision placement and tight flow control an excellent dispensing tool.
Applications already include the use for DNA research, various medical purposes such as dosing of drugs, and food science.

A rather futuristic application is the use of inkjet printing for the fabrication of living tissues.

In any case, the analytic framework combining Technology and Applications is relevant to evaluate at any « M » moment the potential of a technology.

Besides, the detailed understanding of a given technology enables to anticipate, for a specific application, the potential and its limits as far as performance is concerned, of one or another technological branch.

The text above is giving clues about the non-linearity of evolutions in technology.

APPENDIX 5 - Addendum about inkjet history

Coming back to history, Plateau was the very first to publish on this field with his article “On the recent theories of the constitution of jets of liquid issuing from circular orifices”, in 1856. He then derived the relationship between jet diameter and drop size in 1865.
On his side, Lord Rayleigh published a series of founding papers starting with Instability of jets in 1878. The experimental foundation of this work started in 1833, when Savart published his observations on drop break-up. He was the first one who identified that the break-up of liquid jets is governed by laws, independent from the circumstances and conditions of the jet production.
He used acoustic energy to shape uniform drops. But the understanding that surface tension is the driving force behind drop break-up, was missing in his work. The groundwork for the description of surface tension forces and their role was laid sooner by Young in 1804 and Laplace in 1805.
Yet, it took many decades before applications of the physical principles of drop formation were used in commercial and industrial running devices.

In 1951, Elmqvist from the Siemens-Elema company patented the first practical continuous inkjet device (US Patent 2,566,433), based on the Rayleigh breakup laws.
This resulted in the release of a product in 1952. But this Mingograph, rather than targeting inkjet printing, was merely a medical voltage recorder (ECG and EEG applications among others).
The deflection of the drops was driven by analog voltages from a sensor, something quite similar to a regular seismic apparatus.

In the early 1960s, Prof. Sweet from Stanford University demonstrated that, by applying a pressure wave pattern to an orifice, the corresponding fluid stream could be broken into droplets of uniform size and spacing.

When the drop break-up mechanism is under control, each drop can be charged selectively and reliably as it emerges from the continuous fluid flow. The charged drops, passing through an electric field, can then be deflected, so to form an image on the substrate. The uncharged drops are captured by a gutter and continuously re-circulated in the system. This printing process is describing a Continuous Ink Jet (CIJ) mode of printing (US Patent 3,596,275). The first inkjet system of its kind elaborated and used by the Stanford Research Institute (SRI). The Oscillograph was printing barcodes for automatic recognition.
The A.B. Dick Company elaborated Sweet’s invention to be used for alpha numeric character printing. With their Videojet 9600 product, they launched the first commercial CIJ printing machine in 1968.

The binary deflection was further developed, for bar code printing still, but also for advertising purposes, with the so-called DIJIT printer, introduced in 1973 by the Mead company. Developments were mostly boosted by the massive research efforts of IBM in the 1970s, which resulted in the IBM 6640 (1976), a word processing hardcopy-output peripheral.

Two other companies, Applicon and Sharp were also involved in the multiple drop deflection. Sharp released its Jetpoint in the year 1973, and the former its color image printer in 1977.
In the same period, in Sweden, Hertz from the Lund University developed several continuous inkjet techniques, which enabled gray-scale printing thanks to the variation of the number of drops per pixel.
His methods were then adopted by Iris Graphics and Stork to produce high-quality color images for the prepress market.
But, instead of continuously firing drops it is also possible to create droplets only when a pulse is actuated: you get drops “on-demand”!
At origin, drop-on-demand (DOD) printers seemed to present some major advantages over CIJ printers: The facts that there is no need for break-off synchronization, charging or deflection electrodes, guttering, and re-circulation systems, no need either for high pressure ink-supplies and complex electronic circuitry.
The first pioneering work in that direction was performed in the late 1940s by Hansell of the Radio Corporation of America (RCA), who invented the first drop-on-demand device, patented in 1950.
By means of a piezoelectric system, waves are generated that causing an ink spray. But this invention, aiming at grounding a new RCA’s writing mechanism, was not further developed into a commercial product.

But the first DOD technique, that actually emerged, was the electrostatic pull inkjet in the 1960s. The working principle is based on conductive ink held in a nozzle by negative pressure. By applying a high voltage pulse to an electrode in the vicinity of the nozzle, drops of ink are charged then pulled out.
If an appropriate deflection field is managed, the droplet can be accurately directed onto the substrate. Among companies interested in electrostatic pull inkjet devices were Casio, Teletype, Paillard and Inktronik with its Teletype launched in the late 1960s. Casio followed suit in 1971, with the so-called Typuter 500.

The DOD electrostatic pull principle was however commercially abandoned some 10 years later, due to presumed poor printing quality and lack of reliability. But research activities are still going on in this field.

Generally, three patents issued in the 1970s are considered as seminal for Piezoelectric Inkjet Printers (PIJ).
A common denominator among these three patents is the use of a piezoelectrical unit to convert an electrical driving voltage into a mechanical deformation of an ink chamber, which in turn generates the pressure needed to shape a drop from a nozzle.
The patent of Stuart Howkins (US Patent 4,459,601) from Exxon, describing, in 1984, the Push Mode mechanism; and the patent of Fischbeck (US Patent 4,584,590), featuring the Shear Mode, these two patents are completing the commonly adopted taxonomy for DOD PIJ printers.
In short, the mainstream of Digital Printing - DOD PIJ, namely –is gathering 4 main types of print heads (see fig.11).

It is to be mentioned that in the 1960s, another DOD technique was under trial, using principles elaborated by the company Sperry Rand, and based on Sudden Steam Printing.
By bringing aqueous ink to its boiling temperature, drops of ink were generated.
But *the strength of this new design was not immediately acknowledged*, and the company did not elaborate this idea into a commercial product at first.
So, the idea of Thermal Inkjet Printing (TIP) was abandoned until Canon and Hewlett Packard rediscovered it, in the late 1970s.

Indeed, in 1979 Endo and Hara, two engineers from Canon re-invented the drop-on-demand thermal printer, actuated by an ink vapor bubble. Their product, launched in 1981 was the very first to use the so-called "Bubblejet" concept.
The same year, HP developed its own thermal inkjet technology, leading to the first successful low-cost inkjet printer in 1984.
The surge of thermal inkjet (TIJ) was not just a new option in digital printing, but it changed inkjet research!

Indeed, by replacing the piezoelectric system by a thermal transducer, the main bottleneck concerning miniaturization was solved.

For the thermal transducer was resuming to a simple, small, and cheap resistor.

APPENDIX 6 - List of symbols and abbreviations

The below roster aims at facilitating the reading of the various scientific articles attached to the bibliography.

A	Ampere
Al2O3	Aluminium (III) oxide or alumina
at%	Atomic per cent
B	Magnetic flux density
CCVD	Catalytic Chemical Vapour Deposition
chem-FET	Chemical field-effect transistor
CIJ	Continuous inkjet
CNT	Carbon nanotube
DC	Direct current
DMF	Dimethyl formamide
DoD	Drop-on-demand
dpi	Dots per inch
E	Electric field
e,q	Elementary charge
EDS	Energy Dispersive (X-Ray) Spectroscopy
Ekin	Kinetic rotational energy
emu	Electromagnetic unit
eV	Electron volt
FESEM	Field-Emission Scanning Electron Microscopy
FT-IR	Fourier-transform infrared
H	Magnetic field strength
h	Planck's constant
H2S	Hydrogen sulphide
$I_{\parallel}$	Intensity parallel
$I^{\perp}$	Intensity perpendicular
I0	Zero-field intensity
IS-D	Source-drain current
J	Current density
k	Boltzmann's constant
K	Kelvin
LED	Light-Emitting Diod
M	Magnetization

of	Schottky junctions
me	Mass of electron
Mf	Magnetic flux
mmHg	Millimeter of mercury
MWCNT	Multi-walled Carbon Nanotube
OLED	Organic Light Emitting Diode
P	Power
Pa	Pascal
PECVD	Plasma-Enhanced Chemical Vapour Deposition
PEDOT:PSS	Polyethylenedioxythiophene:Polystyrenesulphonate
PIJ	Piezo Ink Jet
ppm	Parts per million
R	Resistance
r0	Initial resistance
R2R	Roll-to-roll or reel-to-reel
RFID	Radio frequency identification
RIE	Reactive ion etching
RND	Random
rpm	Revolutions per minute
s-CNT	Semiconducting carbon nanotube
SEM	Scanning electron microscopy
SPT	Scalable Print head Technology
STM	Scanning tunneling microscopy
SWCNT	Single-wall carbon nanotube
TIJ	Thermal Ink Jet
TMS	Temperature modulated sensing
U	Applied bias
V	Volt
ΔA	Optical dichroism
Δr	Change in resistance
ΔU	Potential energy difference
θ	Angle
λ	Wavelength
Ω	Ohm
Φb	Schottky barrier Height

APPENDIX 7 - Curriculum vitae

B. Calisti is developing a unique combination of operational competencies, academic background and scientific knowledge.
He has been working for more than 30 years in supporting and leading teams in the industrial sector.
As a scholar, he is specializing in High-Tech Entrepreneurship, Innovation Marketing and Management of Technology.
Entrepreneur, Manager and Teacher, he has also over 20 years of experience in advising leaders and managers on development and growth.

INDUSTRY EXPERIENCE

Since 1997 **Entrepreneur and company President:**

Group of SMEs, among them:

- Ardèje corp.

  Venture supported by BPI governmental institution,

  Eurêka distinguished at European level.

  Digital printing Technologies.

- Actidom corp.

  Public/private real estate projects.

  Providing affordable outstanding services to local residents.

- Dracula Technologies S.A.S.

  Organic solar panels.

  Innovation Award Winner, 2012.

From 1987 to 1996 **IMAJE group**

Industrial marking systems.

International Vice-president: marketing and sales.

Operational Manager of the international Division (150 people, 20 nationalities).

Member of the Board of 12 subsidiaries (among them: Japan, Korea, USA, Germany, Mexico).

Covering the 5 continents: > 1500 people, 250 Million € Turnover.

1983-1986 **Cristalleries de Vallérysthal and Simmons-Wikes group (US)**

Regional Sales Director (1984-1986).

Marketing and Sales Manager (1983).

1982 **Military Service in the Navy (Ecole Navale**)

Instructor for senior Officers: "New Methods for the Chain of Command and Operations".

1981 **NESTLE Group (Vevey – Switzerland)**

International Marketing Division.

Junior Product Manager Internship.

FACULTY EXPERIENCE

- Position

Since 2000 **EM-.Lyon, Professor.**

Specialties: Innovation and Entrepreneurship / Corporate Management / Management of Technology.

1997 – 2000 **Lecturer, EM.-Lyon and Ecole Centrale de Lyon**

Strategy, Innovation and industrial marketing

1985 – 1997 **Lecturer for Public and private institutions at University level in France and abroad**
(Ecole des Mines de Paris, CESI, Bauman University (Moscow), Ecole Polytechnique Wroclaw (Poland), Ecole Polytechnique de Lausanne (Switzerland), mainly).

Innovation in Education Award Winner (Epseco/Pigier, 1988)

- Courses taught (selected)

- *Customer orientation with Emory Goizueta University (USA, 2002)*
- *Innovation management (Ecole Centrale de Lyon)*
- *Marketing and customer service (Ecole Polytechnique Fédérale de Lausanne, graduate level)*
- *High-tech marketing (Ecole Polytechnique Fédérale de Lausanne, Switzerland, MBA level)*
- *Launching a new business (EM-Lyon, graduate level)*
- *Entrepreneurial marketing (EM-Lyon, Global Entrepreneurship Program, graduate level)*
- *Strategies for international development (EM-Lyon , graduate level)*
- *Innovation marketing (EM-Lyon , MBA level)*
- *Innovation management (EM-Lyon, MBA level)*
- *Innovation and entrepreneurship (EM-Lyon, graduate level)*
- *Hyper growth and performance (EM-Lyon, MBA level)*

- Executive Education Seminars (Selected)

- SCHNEIDER ELECTRIC GROUP (2001-2009): *International Account Management and Cooperation Strategies: Coventry (in cooperation with Warwick University), Milano, Copenhagen, Paris.*
- SUEZ GROUP (2001-2006): *Customer Orientation Paris, New-York, Bruges, Atlanta*
- SNECMA / THALES UNIVERSITY (2002): *Business Management*
- LAFARGE-HOLCIM (2002-2006): *Marketing New Products and Services, Europe-MEA (Middle-East Africa).*
- MICHELIN (2006-2009): *Marketing Methods and Tools, European Business Units*.
- ALCATEL-LUCENT (2006-2012): *Market oriented and convergence strategies: Budapest, Alexandria, Rabat, Paris, Istanbul.*
- FRANCE TELECOM / ORANGE (2007-2011): *International Talents Program / Innovation Management and sales*
- SAINT-GOBAIN (2011-CTD): *Innovation Management for R&D executives worldwide.*
- ARC INTERNATIONAL (2012-2013): *Entrepreneurial Marketing, Chantilly and Arques, France*.
- VEOLIA (2013): *B2B Marketing and Strategy, Paris, Shanghaï*.
- EUROPEAN JOINT INNOVATION CENTRE (ITALY) : *Tutoring of awarded startups and entrepreneurs at European scale*

CONSULTING (SELECTED)

- FF3C: *international conference (Crete 2008), national board meeting 2010, steering committee advisor (2008 -2011)*
- SUEZ, USA: ATLANTA (DECEMBER 2001) AND NYC (JANUARY 2002), *implementing Suez culture and strategic process in newly acquired companies.*
- SCHNEIDER ELECTRIC: *innovation and cooperation (Europe and Middle East).*
- LAFARGE -HOLCIM: *innovation and business development (France)*
- ALCATEL LUCENT: *innovation and management (Europe, Middle-East and Asia)*
- ORANGE: *tutoring innovative internal projects for High Pos. (worldwide)*
- MANY SMES ADVISED (MORE THAN 100): LASER GAME EVOLUTION, MECELEC, VELAN … *topics: innovation, business development and strategy.*
- PUBLIC INSTITUTIONS : ALSACE INNOVATION AGENCY, RHONE-ALPS INNOVATION AGENCY, RDT PAYS DE LOIRE, RDT BRETAGNE, CENTER FOR TECHNOLOGY TRANSFER (AUVERGNE), RDT NORD PAS DE CALAIS.
- OTHER ORGANIZATIONS: PROMOBOIS , FIBRA, CRITTS.

RESEARCH AND PUBLICATIONS

- Books

AN ALTERNATIVE VISION OF PERFORMANCE (ED. ORGANISATION, 2005)

- Book Chapters

- *Innovation in SMEs. (Guide du Développeur économique. Territorial Edition, 2008)*
- *Entrepreneuriat (Pearson Education, 2009)*
- *Essentials of Logistics and Management (EPFL Press, 2012)*

- Articles and Conferences (Selected)

- *SMEs' Development in China (Le MOCI, 1995)*
- *L'avenir est à ceux qui innovent (Economie Drômoise, Octobre 2004)*
- *How to Develop a Societal Offering : Social acceptability in small construction projects (Academic Article written with Stefano Pace, Bernard Cova and Robert Salle; IMP, 2004)*
- *Innovation (CCI Nord Isère N°53, 2005)*
- *Innovation Marketing (CCI Nord Isère N°65, 2008)*
- *Performance and Management (HR Today, 2009)*
- *The Human Side of Innovation / l'Innovation? plus Humaniste que Mécaniste, (Critt , 2011)*
- *Innovation and Entrepreneurship (Réseau Entreprendre National Conference, 2012)*
- *The Dynamics of Industrial Emergence: Insights from Ink Jet Technology Clusters (Academic: IMP, 2013)*
- *Managing in Chaos / Piloter dans l'Incertitude (Critt Savoie, October 2012)*
- *Management for the 21st Century: Favoring the Emergence of Sensitive Companies (CRQP 30th anniversary year Conference in Switzerland, February 2013)*
- *Best Practices in Innovation for Service companies (Themavision, 2014)*
- *Outliers and Russian Dolls: Hidden Drivers of Hyper Growth (IMP, 2014)*
- *Several interviews in magazines such as: L'Express, l'Expansion and l'Usine Nouvelle*
- *Innovation Without Computer (Géoéconomie, 2016).*

- Cases and Technical Notes (Publicly available)

- *Neod: Market Shaping, EM-Lyon 2003*
- *Inuit: Italian Digital Printers and Strategic Risk Approach*, EM-Lyon, 2010
- *Laser Game Evolution: Growth and Crisis in Entrepreneurship, EM-Lyon, 2012*

EDUCATION

After receiving in parallel a Master of Science in Management and a DEA degree of Science in Epistemology, I completed my education with pedagogical and business certificates such as PERFECAD and CESA-HEC Paris.

A dual Academic background:

- Graduates in Business Administration

- Master in Science DESCAF / ESC ("Grande Ecole" Program) from EUROMED Marseille-Luminy, 1981.
- Completed the Bachelor DESCAF/ ESC Program from EUROMED Marseille-Luminy, 1979-1980.
- Completed the Classe préparatoire aux Concours des Grandes Ecoles Program from Lycée Thiers, Marseille, 1978.

- Graduates in Academic Sciences and Philosophy

- D.E.A. from Aix-Marseille University, 1982.
  Major: Epistemology
- Master of Science from Aix- Marseille University, 1981.
  Major Philosophy of sciences   Minor: Computing Sciences and maths
- Bachelor of Science from Aix-Marseille University, 1978 – 1980.

- Other certificates and diploms:

- *Completed the Perfecad Program from the Navy ministry, 1982*
- *Completed the CESA Program from HEC-Paris, 1990.*

PROFESSIONAL MEMBERSHIPS, AWARDS AND ACCOMPLISHMENTS

- ACADEMY OF MANAGEMENT
- FOUNDER OF THE REGIONAL INNOVATION CLUB
- EM-LYON PGM PROGRAM COMMITTEE
- EM-LYON MBA PROGRAM COMMITTEE
- EM-LYON ACADEMIC JOINT COMMITTEE (ELECTED FACULTY REPRESENTATIVE)
- MANAGEMENT BOOK OF THE YEAR / SYNAPSIS 2005, FINALIST.
- WORLD ENTREPRENEURSHIP FORUM SCIENTIFIC COMMITTEE
- MEMBER OF THE BOARD OF IFEC FRANCE (WPO ASSOCIATE)
- FOUNDER AND ADMINISTRATOR OF THE REGIONAL PUBLIC CENTRE FOR INNOVATION IN TRACEABILITY
- MOT ACADEMIC ADVISORY BOARD
- IMP GROUP
- FOUNDER OF 7 STARTUPS AND NEW COMPANIES (INCLUDING ARDEJE, DRACULA TECHNOLOGIES AND ACTIDOM)
- PRODUCT OF THE YEAR AWARD WINNER (IMAJE S7, 1993)
- INNOVATION AWARD WINNER (FRENCH TECH. ARTINNOV 2012)
- ADDITIONAL AWARDS FOR DRACULA TECHNOLOGIES : KICKINNO ENERGY AWARD (2013), BPI EXCELLENCE DISTINCTION (2014), VIVA TECHNOLOGIES AWARD (2015)
- "GAZELLE" NOMINATION FOR ARDEJE BY THE FRENCH MINISTRY OF RESEARCH.

EXPERTISE

To share knowledge about managing disruptive innovation projects for high growth and to foster companies' performance.

ENDNOTES

---

[1] The minor difference between the two patents mentioned, is that Stemme used a flat disc of piezoelectric material to deform a rear wall of an ink chamber when Kyser and Sears used a rectangular plate to deform its roof.
[2] The bend mode is also referred to as bimorph or unimorph mode.
[3] Obviously, the main discriminator between the PIJ patents is the deformation mode of the piezoelectric material, together with the geometry of the ink channels.
[4] With the push mode, also referred to as bump mode, a piezo electric element pushes against an ink chamber wall to deform the ink chamber.
In the shear mode the strong shear deformation component in piezo electric materials is used to deform an ink chamber wall.
[5] Presently, the bump mode actuation is used by Hitachi (which acquired Dataproducts), Trident, Brother and Epson.
The bend mode is used by Tektronix (acquired by Xerox), Brother/Kyocera and Epson. (see fig. Inkjet Technologies family / P Giraud)
[6] A solution was later found by using silver.
[7] SIJ is in fact using a piezo technology.
[8] Super Fine = less than 1 pico Thermal or Piezo inkjet (HP, Memjet)
Electrostatic: Xerox (past) or Tonejet (slightly different).
Hertz is now obsolete! Used by Stork in the 80ies (textile application).
Multiple Deflection (Jemtex): 2 positions past the nozzle!
[9] Valv Spray is part of DOD technology!
Droplet charge deflection is part of the Binary deflection branch.
[10] Another way to show the linearity would be to position on a scale the main evolutionary stages of the inkjet technology from the 17th century (Kelvin … Sweet … SCP …).
[11] Further research would favorably explore and display the existing bonds between the 3 early actors of SCP technology worldwide. Such a sociogram would again reveal the hidden complexity in the evolutionary history of inkjet.
[12] We could argue that INCA digital (DOD) was as successful in terms of international coverage and number of employees as APS (CIJ) was. But what about their value? Just compare the selling price value of INCA (30 M pounds) and that of APS.
[13] The King Kong Effect exposed is somewhat reminiscent of phenomena related to hormesis. Even if at a different scale. The image of King Kong is indeed very different from the image of a small dose of anything as in hormosis processes. The German pharmacologist Hugo Schulz first described such a phenomenon in 1888 following his own observations that the growth of yeast could be stimulated by small doses of poisons. This was coupled with the work of German physician Rudolph Arndt, who studied animals given low doses of drugs, eventually giving rise to the Arndt-Schulz rule. Arndt's advocacy of homeopathy contributed to the rule's diminished credibility in the 1920s and 1930s. The term "hormesis" was coined and used for the first time in a scientific paper by C.M. Southam and J. Ehrlich in 1943 (Wikipedia).
14 Greater volatility of the cascading type: can be applied to the generation of spinoffs from an outlier. As stated in Antifragile Book 2: Depriving systems of volatility harms them, eventually causing greater volatility of the cascading type.
15 Non linearity: Linear function. Similar differences between the various years.
16 The hidden variable considered in the text is coming from a series of concepts developed in various fields of science. Hidden variable is thus referring to Kolmogorov's axiomatisation of probabilities, to Ω as innumerable infinite, to absolute random in quantum physics, or to Cauchy's infinite mathematical expectancy and variance.