The Process of Innovation: Obstacles and Complementarities

Fabrice GALIA
Burgundy School of Business - BSB
CEREN - Dept. of Organisation Management and Entrepreneurship
Chair MIR - Management and Responsible Innovations
Chair Corporate Governance

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The Process of Innovation: Obstacles and Complementarities

1. The process of innovation

2. Innovation measures and CIS - Community Innovation Survey

3. Obstacles to Innovation
   3.1. Obstacles to innovation – Study #1 (RP, France, 2004)
   3.2. Obstacles to innovation – Study #2 (ICBM, France and Italy, 2015)

1. The process of innovation

Oslo Manual (2005) classifies four main forms of innovation:

- **Product**, **Process**, **Organizational** and **Marketing** innovations

**Innovation** is defined as **major changes** aimed at enhancing your **competitive position**, your **performance**, your **know-how** or your **capabilities** for future enhancements.
1. The process of innovation

- The traditional process of innovation
  Sequential chain “Sources-Innovation-Performance”

- The modern process of innovation
  - Integration of the Organizational Innovations and Marketing Innovations
  - Implications for environment, CSR, and Sustainable Development

- Board diversity and innovation

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**DIAGRAM:**

- **R&D Decision** → **R&D Investment**
- **Products Innovations** → **Process Innovations** → **Organizational Innovations** → **Marketing Innovations**
- **Innovations Protection Strategies** (IPR, Patents, Trademarks, Secrets,...)
- **Performances** (Turnover, VA, Employment, Market share, %Turnover, Innovating Products,...)
- **Innovations with environmental benefits**
- **Board Diversity**
- **Obstacles to Innovation**

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**THE PROCESS OF INNOVATION: OBSTACLES, COMPLEMENTARITIES AND DYNAMICS**

Fabrice GALIA - Burgundy School of Business - BSB Dijon - France
Universidad Diego Portales - Santiago - Chile - May 24th, 2017
1. The process of innovation

**Oslo Manual (2005)** classifies four main forms of innovation:

- **Product**, **Process**, **Organizational** and **Marketing** innovations

- **Product and Process innovations** within the topic of **Technological Innovations**
  - Demand pull
  - and/or Technology push

- **Organizational and Marketing innovations** within the topic of **Management Innovations** or **Non-Technological Innovations**
  - Understanding of organizational innovations
  - Potential source of competitive advantage
2. Innovation measures and CIS - Community Innovation Survey

French Community Innovation Survey (CIS) since 1990 (3 year period)
INSEE - National Statistical Office in France (20 000 firms - 8th wave in 2010-2012)

- Innovation 1991 – Appendix of EAE "Firm Annual Survey" (1986-90)
- CIS1 (1990-92)
- CIS2 (1994-96)
- CIS3 (1998-00)
- CIS4 (2002-04)
- CIS5 (2004-06) "Overlapping data" with three years' CIS length Eurostat requirement
- CIS6 (2006-08)
- CIS7 (2008-10)
- CIS8 (2010-12)

2. Innovation measures and CIS - Community Innovation Survey

Community Innovation Survey (CIS) since 1990 (3 year period)
INSEE - National Statistical Office in France (20,000 firms - 8th wave in 2010-2012)

- General information (size, sales, sector...)

- **Product (good or service) innovations [2 types] (0,1)**
  - New to the *market*
  - Only new to the *firm*

"A **product innovation** is the market introduction of a **new** good or service or a **significantly** improved good or service with respect to its **capabilities**, such as quality, user friendliness, **software** or **subsystems**.

The innovation must be new to your enterprise, but it does not need to be new to your market.

It does not matter if the innovation was originally developed by your enterprise or by other enterprises."
2. Innovation measures and CIS - Community Innovation Survey

Community Innovation Survey (CIS) since 1990 (3 year period)
INSEE - National Statistical Office in France (20 000 firms - 8th wave in 2010-2012)

- General information (size, sales, sector...)
  - Product (good or service) innovations [2 types] (0,1)
    - New to the market
    - Only new to the firm
  - Process innovations [3 types] (0,1)
    - New or significantly improved methods for the manufacture or production
    - New or significantly improved logistics systems or delivery or distribution
    - New or significantly improved supports activities for its processes
  - Innovation activity in progress or abandoned (0,1)
    - If at least one YES among three: Firm is defined as technological innovative firms
    - If NO to these 3 questions go directly to questions on Org. and Mkg. Innovations
2. Innovation measures and CIS - Community Innovation Survey

Community Innovation Survey (CIS)

- Innovation activities and expenditures
- Sources of information and co-operation for innovation
- Effects of innovations
- Objectives of innovations

- Obstacles to innovation: projects or activities of innovation
  - *Abandoned during conception / Abandoned at the beginning / Delayed projects*
    
    *Only for firms with technological innovating activities (Product, Process or Project)*
  
  - CIS 2, 3, 4, 5 and 7 for all firms
  - CIS 9 only for non-innovating firms

- Obstacles to innovation for all firms *(Financial, Knowledge, Market obstacles)*

- Environmental benefits of innovation
- Strategies to reach objectives of the firm
- Protection methods for innovation
2. Innovation measures and CIS - Community Innovation Survey

Community Innovation Survey (CIS)

- **Organizational Innovations [4 types] (0,1)**

  - *New business practices in the organization of the work or of the company procedures*
  
  - *New knowledge management systems to improve the use or exchange of information, knowledge and ability, within the company, or so as to collect information outside of the Company*
  
  - *New organization methods for the workplaces in the company, for the purpose of a better distribution of responsibilities and decision-making*
  
  - *New management models for external relations with other companies or public institutions*
2. Innovation measures and CIS - Community Innovation Survey

Community Innovation Survey (CIS)

- **Marketing Innovations [4 types] (0,1)**
  
  - **Design**: If the firm introduces significant modifications in the design of the product or in the packaging of the goods or services
  
  - **Product promotion**: If the firm introduces new techniques or channels for the promotion of the product
  
  - **Product positioning**: If the firm introduces new methods for the positioning of the product in the market or sales channels
  
  - **Establishing prices**: If the firm introduces new methods for establishing the prices of the goods or services
3. Obstacles to innovation

Studies on obstacles to innovation using Community Innovation Survey (CIS):

- Mainly aimed at understanding their impact on firm's attitude towards R&D activities and propensity/intensity of innovation (Arundel, 1997; Asso and Vito, 2010; Blanchard et al., 2012; Hyytinen and Toivanen, 2005; Mohnen and Röller, 2005; Mohnen et al., 2008; Savignac, 2008; Segarra-Blasco et al., 2007; Tiwari et al., 2008; Tourigny and Le, 2004; Mancusi and Vezzulli, 2010; Wziatek-Kubiak and Peczkowski, 2011)

- Minor attention has been paid to the determinants of obstacles to innovation (Baldwin and Lin, 2002; D’Este et al., 2012; Galia and Legros, 2004; Hölzl and Janger, 2011; Iammarino et al., 2009; Mohnen and Rosa, 2000; Schneider and Veugelers, 2008; Tourigny and Le, 2004)
3. Obstacles to innovation

Obstacles to innovation:

- **Cost and Financial**
- **Knowledge**
- **Market**
- **Institutional**
- **Other reasons for not innovating**

(Oslo Manual, 2005)
3.1. Obstacles to innovation – Study #1 (RP, France, 2004)

Community Innovation Survey (CIS)

<table>
<thead>
<tr>
<th>Obstacles</th>
<th>Description</th>
<th>Postponed projects (%)</th>
<th>Abandoned projects (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBS1 ECO RISK</td>
<td>Excessive perceived economic risk</td>
<td>21.3</td>
<td>18.7</td>
</tr>
<tr>
<td>OBS2 COSTS</td>
<td>Innovation costs too high</td>
<td>19.9</td>
<td>14.7</td>
</tr>
<tr>
<td>OBS3 FINANCING</td>
<td>Lack of appropriate source of finance</td>
<td>13.8</td>
<td>5.8</td>
</tr>
<tr>
<td>OBS4 RIGID ORG</td>
<td>Resistance of change in the firm (rigid organization)</td>
<td>16.6</td>
<td>3.3</td>
</tr>
<tr>
<td>OBS5 SKILLED</td>
<td>Lack of skilled personnel</td>
<td>21.2</td>
<td>3.4</td>
</tr>
<tr>
<td>OBS6 INFO TECH</td>
<td>Lack of information on technologies</td>
<td>17.0</td>
<td>5.5</td>
</tr>
<tr>
<td>OBS7 INFO MARK</td>
<td>Lack of information on markets</td>
<td>16.2</td>
<td>4.4</td>
</tr>
<tr>
<td>OBS8 INSTITUT</td>
<td>Legislation, regulations, norms, standards</td>
<td>14.2</td>
<td>3.7</td>
</tr>
<tr>
<td>OBS9 CUSTOMER</td>
<td>Lack of customer responsiveness to new products and processes</td>
<td>18.8</td>
<td>9.2</td>
</tr>
<tr>
<td>Met at least one obstacle</td>
<td></td>
<td>67.6 (1197)</td>
<td>39.3(696)</td>
</tr>
</tbody>
</table>

*Source: SESSI (1997).*

**CIS2 -1994-96:** main obstacles are, compared to financial constraints:
- Lack of skilled personnel
- Resistance of change in the firm (rigid organization)

Complementarities and innovation

**Complementarities:**

Intuitive ideas of *synergies, systems* effects and *mutual* reinforcement

*i.e. “the whole is more than the sum of the parts”*

**Mathematical concept of lattices and qualitative variables (0,1)**


*A practice is more likely to be adopted at a higher level if other practices are adopted at high level, too*
Empirical literature studying complementarities between various practices or strategies:

Three types of approaches - Athey and Stern (1998):

1 - Testing the positive correlation between various practices conditional on a certain number of common explanatory variables (CORR)

2 - Factor which has an effect on one variable will not be correlated with another variable unless the variables are complementary (RED)

3 - Modeling firm's objective function by a set of regressors, including the interactions effects or clusters between several practices or strategies (PROD)

+ 3 ext. - Theoretical concept of supermodularity within the mathematical concept of lattices (SUPERMOD)
3.1. Obstacles to innovation – Study #1 (RP, France, 2004)

- Multivariate probit model: 9 equations estimating the 9 obstacles to innovation

- Estimate of the disturbance covariance matrix

Table 4
Multivariate probit model of obstacles to innovation in postponed projects (1772 firms)

<table>
<thead>
<tr>
<th></th>
<th>ECO RISK</th>
<th>COSTS</th>
<th>FINANCING</th>
<th>RIGID ORG</th>
<th>SKILLED</th>
<th>INFO TECH</th>
<th>INFO MARK</th>
<th>INSTITUT</th>
<th>CUSTOMER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.900*** (0.146)</td>
<td>-0.821*** (0.151)</td>
<td>-1.182*** (0.163)</td>
<td>-1.380*** (0.165)</td>
<td>-0.908*** (0.151)</td>
<td>-1.264*** (0.172)</td>
<td>-1.312*** (0.162)</td>
<td>-1.280*** (0.170)</td>
<td>-1.117*** (0.157)</td>
</tr>
<tr>
<td>No empl. (log)</td>
<td>0.011 (0.032)</td>
<td>0.020 (0.032)</td>
<td>0.022 (0.036)</td>
<td>0.040 (0.035)</td>
<td>0.023 (0.031)</td>
<td>-0.011 (0.034)</td>
<td>0.015 (0.034)</td>
<td>-0.019 (0.034)</td>
<td>-0.003 (0.033)</td>
</tr>
<tr>
<td>Med. low tech.</td>
<td>-0.184** (0.090)</td>
<td>0.038 (0.095)</td>
<td>-0.019 (0.106)</td>
<td>-0.070 (0.099)</td>
<td>0.069 (0.091)</td>
<td>0.019 (0.101)</td>
<td>0.065 (0.099)</td>
<td>0.182 (0.116)</td>
<td>-0.032 (0.094)</td>
</tr>
<tr>
<td>Med. high tech.</td>
<td>0.098 (0.100)</td>
<td>0.154 (0.103)</td>
<td>0.042 (0.096)</td>
<td>0.039 (0.091)</td>
<td>0.091 (0.106)</td>
<td>0.228* (0.106)</td>
<td>0.475*** (0.122)</td>
<td>0.665 (0.101)</td>
<td>0.019 (0.107)</td>
</tr>
<tr>
<td>High tech.</td>
<td>-0.185 (0.140)</td>
<td>0.041 (0.142)</td>
<td>0.072 (0.159)</td>
<td>-0.315** (0.157)</td>
<td>-0.243* (0.151)</td>
<td>-0.083 (0.146)</td>
<td>-0.051 (0.151)</td>
<td>0.587*** (0.151)</td>
<td>-0.394* (0.154)</td>
</tr>
<tr>
<td>French group</td>
<td>-0.064 (0.104)</td>
<td>-0.215* (0.105)</td>
<td>-0.337*** (0.117)</td>
<td>0.050 (0.119)</td>
<td>0.015 (0.104)</td>
<td>0.064 (0.111)</td>
<td>0.307*** (0.120)</td>
<td>-0.019 (0.107)</td>
<td>0.036 (0.112)</td>
</tr>
<tr>
<td>Foreign group</td>
<td>-0.087 (0.110)</td>
<td>-0.344*** (0.107)</td>
<td>-0.438*** (0.117)</td>
<td>0.107 (0.117)</td>
<td>0.127 (0.106)</td>
<td>0.029 (0.113)</td>
<td>0.085 (0.112)</td>
<td>0.206** (0.116)</td>
<td>0.123 (0.107)</td>
</tr>
<tr>
<td>Internal R&amp;D</td>
<td>0.213 (0.097)</td>
<td>0.102 (0.097)</td>
<td>0.169 (0.113)</td>
<td>0.258** (0.112)</td>
<td>0.100 (0.107)</td>
<td>0.135 (0.105)</td>
<td>0.161 (0.114)</td>
<td>0.271** (0.118)</td>
<td>0.124 (0.105)</td>
</tr>
<tr>
<td>External R&amp;D</td>
<td>-0.169 (0.084)</td>
<td>-0.058 (0.086)</td>
<td>0.134 (0.093)</td>
<td>0.088 (0.090)</td>
<td>0.070 (0.088)</td>
<td>0.020 (0.083)</td>
<td>0.008 (0.085)</td>
<td>0.118 (0.086)</td>
<td>0.008 (0.085)</td>
</tr>
<tr>
<td>Training</td>
<td>0.179 (0.077)</td>
<td>0.094 (0.082)</td>
<td>0.110 (0.092)</td>
<td>0.029 (0.086)</td>
<td>0.205** (0.077)</td>
<td>0.083 (0.083)</td>
<td>0.032 (0.084)</td>
<td>0.067 (0.091)</td>
<td>0.016 (0.082)</td>
</tr>
<tr>
<td>Cooperation</td>
<td>0.084 (0.079)</td>
<td>0.222*** (0.083)</td>
<td>0.112 (0.091)</td>
<td>0.038 (0.084)</td>
<td>0.088 (0.079)</td>
<td>0.189** (0.086)</td>
<td>0.074 (0.086)</td>
<td>0.011 (0.083)</td>
<td>0.161*** (0.083)</td>
</tr>
</tbody>
</table>

Between parentheses are standard deviation. Correlation coefficients in bold indicate higher values of correlation. Source: SESSI (1997).

Table 5
Estimate of the disturbance covariance matrix—obstacles to innovation in postponed projects (1772 firms)

<table>
<thead>
<tr>
<th></th>
<th>ECO RISK</th>
<th>COSTS</th>
<th>FINANCING</th>
<th>RIGID ORG</th>
<th>SKILLED</th>
<th>INFO TECH</th>
<th>INFO MARK</th>
<th>INSTITUT</th>
<th>CUSTOMER</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECO RISK</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COSTS</td>
<td>0.37(0.044)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FINANCING</td>
<td>0.29(0.051)</td>
<td>0.44(0.045)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIGID ORG</td>
<td>0.10(0.052)</td>
<td></td>
<td>0.46(0.043)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SKILLED</td>
<td>0.12(0.049)</td>
<td></td>
<td></td>
<td>0.41(0.046)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INFO TECH</td>
<td>-0.02 (0.053)</td>
<td></td>
<td></td>
<td></td>
<td>0.49(0.041)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INFO MARK</td>
<td>0.17 (0.051)</td>
<td></td>
<td></td>
<td></td>
<td>0.41(0.047)</td>
<td>0.41(0.047)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INSTITUT</td>
<td>0.18 (0.054)</td>
<td></td>
<td></td>
<td></td>
<td>0.42 (0.050)</td>
<td>0.33 (0.047)</td>
<td>0.37 (0.052)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>CUSTOMER</td>
<td>0.23 (0.048)</td>
<td></td>
<td></td>
<td></td>
<td>0.27 (0.049)</td>
<td>0.19 (0.048)</td>
<td>0.29 (0.048)</td>
<td>0.50 (0.046)</td>
<td>1</td>
</tr>
</tbody>
</table>
3.1. Obstacles to innovation – Study #1 (RP, France, 2004)

- Multivariate probit model: 9 equations estimating the 9 obstacles to innovation

<table>
<thead>
<tr>
<th>Table 6</th>
<th>Multivariate probit model of obstacles to innovation in abandoned projects (1772 firms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-1.624*** (0.160)</td>
</tr>
<tr>
<td>No. emp. (log)</td>
<td>0.112*** (0.032)</td>
</tr>
<tr>
<td>Med. low tech.</td>
<td>-0.187*** (0.096)</td>
</tr>
<tr>
<td>Med. high tech.</td>
<td>0.079 (0.105)</td>
</tr>
<tr>
<td>High tech.</td>
<td>-0.104 (0.137)</td>
</tr>
<tr>
<td>French group</td>
<td>0.088 (0.108)</td>
</tr>
<tr>
<td>Foreign group</td>
<td>-0.006 (0.113)</td>
</tr>
<tr>
<td>Internal R&amp;D</td>
<td>0.172 (0.110)</td>
</tr>
<tr>
<td>External R&amp;D</td>
<td>0.025 (0.089)</td>
</tr>
<tr>
<td>Training</td>
<td>-0.082 (0.083)</td>
</tr>
<tr>
<td>Cooperation</td>
<td>0.132 (0.085)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 7</th>
<th>Estimate of the disturbance covariance matrix—obstacles to innovation in abandoned projects (1772 firms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECO RISK</td>
<td>1</td>
</tr>
<tr>
<td>COSTS</td>
<td>0.48 (0.044)</td>
</tr>
<tr>
<td>FINANCING</td>
<td>0.53 (0.062)</td>
</tr>
<tr>
<td>RIGID ORG</td>
<td>0.61 (0.081)</td>
</tr>
<tr>
<td>SKILLED</td>
<td>0.49 (0.011)</td>
</tr>
<tr>
<td>INFO TECH</td>
<td>0.54 (0.085)</td>
</tr>
<tr>
<td>INFO MARK</td>
<td>0.49 (0.014)</td>
</tr>
<tr>
<td>CUSTOMER</td>
<td>0.52 (0.077)</td>
</tr>
</tbody>
</table>

Between parentheses are standard deviation. Correlation coefficients in bold indicate higher values of correlation. Source: SESSI (1997).
3.1. Obstacles to innovation – Study #1 (RP, France, 2004)

Economic and managerial implications of complementarities between obstacles

- Futile to combat them individually and separately
- Synergies in a coherent manner
3.2. Obstacles to innovation – Study #2 (ICBM, France and Italy, 2015)

Different types of obstacles:

- **Revealed barriers** to innovation: reflects the degree of difficulty of the innovation process and the learning experience consequent on the firm engaging in innovation activity

- **Deterring barriers** to innovation: encompasses the obstacles that prevent firms from committing to innovation


Determinants of obstacles to innovation within innovation profiles:

- **Innovators**: firms that introduce product or process innovation *(6364 firms, 30.7%)*

- **Innovative active**: firms engaged into innovation activities but without reaching the expected output *(1063 firms, 5.1%)*

- **Non-innovative active**: firms not involved in innovation activities *(13320 firms, 64.2%)*

3.2. Obstacles to innovation – Study #2 (ICBM, France and Italy, 2015)

For each innovative profile the predominant impediments are internal financial constraints, innovation costs too high, market dominated by established firms and uncertain demand for innovative goods or services. The only evident difference among innovation profiles is the entity of economic barriers perceived by Innovative-active firms that suggests that the high costs involved in innovation projects and the lack of internal financial resources have a high probability to delay or give up the innovation development.
3.2. Obstacles to innovation – Study #2 (ICBM, France and Italy, 2015)

CIS4 in France and Italy: “L'Innovation” - Community Innovation Survey (CIS) 2002-2004 - 20,747 manufacturing and services sectors firms

Predominant impediments for each innovative profile:

- internal financial constraints
- innovation costs too high
- market dominated by established firms
- uncertain demand for innovative goods or services

The only evident difference among innovation profiles:

- economic barriers perceived by Innovative-active firms

suggests that the high costs involved in innovation projects and the lack of internal financial resources have an high probability to delay or giving up the innovation development
3.2. Obstacles to innovation – Study #2 (ICBM, France and Italy, 2015)

- **Multivariate probit models** explaining obstacles to innovation that allow taking into account the **possible interdependence** between the perception of different types of obstacles

**Dependent variables:**

- Types of innovation activities: Internal R&D, External R&D, Equipment, Knowledge, Training, Marketing, Cooperation
- Sources of information (9 types)
- Ability to appropriate the results of innovative activities
- Public financial support: National, EU
- Wider innovation: Organizational, Marketing
- Size
- High growth
- Group membership
- Industry dummies
- Competition
- International and/or national market
- Country specific effect (impact of national innovation system)
3.2. Obstacles to innovation – Study #2 (ICBM, France and Italy, 2015)

**Stimulating and accelerating innovation performance**

*Innovators*

- Country specific policies supporting internal R&D, training programs and openness of the firms.
- Reinforce the National and European public policies.

**Supporting innovation by reducing failures**

*Innovative active firms*

- Support internal R&D and openness of the firms.
- Reinforce the national variations and National public subsidies.

**Encouraging innovative effort**

*Non-Innovative active firms*

- Policies targeted to technological innovations linked to other forms of innovation: organizational and marketing innovations.
3.2. Obstacles to innovation – Study #2 (ICBM, France and Italy, 2015)

Pro-innovation public policies should take into account that the causes of the perception of obstacles vary across innovation profiles

Thus, both to stimulate the involvement of Non-innovative active firms in innovation activities, to enhance innovative efforts of the other firms and to help firms in introducing innovation, pro-innovation policies should aim:

- First: reducing economic and financial obstacles
- Secondly: helping firms in facing market-related obstacles

Nature of the most perceived obstacles is similar across the three innovation profiles (Innovators, Innovative active and Non-innovative active):

- internal financial constraints, innovation costs too high, market dominated by established firms and uncertain demand for innovative goods or services
- Hampering effect of innovation costs is more evident for Innovative active firms
3. Obstacles to innovation: Conclusion

- Better understanding of the factors hampering innovation and the determinants of these obstacles in order to suggest **how innovation could be stimulated or facilitated**

- Nature of the most perceived obstacles seems to be similar across the firms' innovation profiles: internal financial constraints, innovation costs too high, market dominated by established firms and uncertain demand for innovative goods or services

- Hampering effect of **innovation costs** is more evident for **Innovative active firms**

- However, the drivers of the perception of obstacles vary across different types of obstacle and, at the same time, vary across innovation profiles

- Thus, **public policies** aimed at **supporting innovation development** may **differ from** the ones targeted to encourage innovation activities
3. Obstacles to innovation: Conclusion

Next steps:

- panels of CIS data avoiding overlapping of data period
- international comparison including France and Italy
- disaggregated analysis of sectors (manufacturing / services)
- link information focused on obstacles to innovation and cooperation
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

Explore the **triangle** of relationships between:

- **Product innovation**
- **Process innovation**
- and **Organizational innovation**

4. The Fateful Triangle

- Explore the **triangle** of relationships between:
  - Product innovation
  - Process innovation
  - and Organizational innovation

- Examine the **complementarities-in-performance**: the effects of complementarities and substitutions between these forms of innovation on the performance of the firms

- Implement a **new testing procedure** for complementarity: *conditional vs. unconditional* tests

- Test if the triangle depends on:
  - National context: France and the UK
  - Size of firms
  - Capabilities of firms (R&D)

---

4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

Motivation

➢ Results should bring some light on:

- **Theoretical issues**: the firm according to Milgrom & Roberts (1990) benefits from having certain complementary practices

- **Is this prediction supported by the data** (i.e. all innovation forms complementary)?

- **If not, are there partial complementarities**?

- **Foundations for the theory**: new products may require new processes and new methods of management, marketing... (Damanpour & Evan, 1984; Damanpour, 1991; Freeman & Soete, 1997; Birkinshaw, Hamel & Mol, 2008; Mol & Birkinshaw, 2009)...
Empirical literature studying complementarities between various practices or strategies:

**Three types of approaches** - Athey and Stern (1998):

1. Testing the positive correlation between various practices conditional on a certain number of common explanatory variables (CORR)

2. Factor which has an effect on one variable will not be correlated with another variable unless the variables are complementary (RED)

3. Modeling firm's objective function by a set of regressors, including the interactions effects or clusters between several practices or strategies (PROD)

+ 3 ext. - Theoretical concept of supermodularity within the mathematical concept of lattices (SUPERMOD)
Innovation and complementarities literature

Two axes of economic/management literature on sources of innovation and the effects of innovation on firm performance

- First axis: Sequential chain “Sources-Innovation-Performance”

Long history of econometric studies on the effects of R&D on technological innovation and the two main forms: product and process


Recent extensions on organizational and marketing innovation: Mol & Birkinshaw (2009), Schmidt & Rammer (2007)
Innovation and complementarities literature

Two axes of economic/management literature on sources of innovation and the effects of innovation on firm performance

- Second axis: Complementarities and innovation

**Complementarities:**
Intuitive ideas of *synergies*, *systems* effects and *mutual* reinforcement

*i.e. “the whole is more than the sum of the parts”*

**Mathematical concept of lattices and qualitative variables (0,1)**


*A practice is more likely to be adopted at a higher level if other practices are adopted at high level, too*
Two axes of economic/management literature on sources of innovation and the effects of innovation on firm performance

Second axis: Complementarities and innovation

a) “Traditional” methods - Complementarities-in-use: two sets of activities are linked, the use of one practice often requires the use of other practices

b) Supermodularity theory and tests - Complementarities-in-performance: performance effects of the use of different practices in combination with one another
   i) General theory: Milgrom & Roberts (1990, 1995)

c) Trying to study the innovation chain and the complementarities in innovation forms: Polder, Leuwen, Mohnen, Raymond (2010, being revised)
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

France and UK CIS4 - 2002-2004, Manufacturing firms

Total sample of firms for the Heckman test
- UK: 3627 firms
- France: 5691 firms
- Pooled: 9318 firms

Sample of firms which innovate or try to innovate used for the production functions of the innovation forms
- UK: 2014 firms
- France: 3201 firms
- Pooled: 5215 firms

Table 1: Definition of variables and descriptive statistics (firms with technological innovating activities – Product, Process or Project – and all firms¹)

<table>
<thead>
<tr>
<th>Name of variables</th>
<th>Description</th>
<th>Pooled 5215 firms (9318 firms)</th>
<th>UK 2014 firms (3627 firms)</th>
<th>France 3201 firms (5691 firms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product innovation</td>
<td>If the firm introduces a product that is new-for-the-market (0,1)</td>
<td>50.74% (28.40%)</td>
<td>49.35% (27.40%)</td>
<td>51.61% (29.03%)</td>
</tr>
<tr>
<td>Process innovation</td>
<td>If the firm introduces a new process (0,1)</td>
<td>67.69% (37.88%)</td>
<td>55.16% (30.63%)</td>
<td>75.57% (42.50%)</td>
</tr>
<tr>
<td>Organizational innovation</td>
<td>If one of the following: new or significant improved organizational structure, system for managing knowledge, or marketing activities (0,1)</td>
<td>63.97% (46.39%)</td>
<td>60.43% (43.64%)</td>
<td>66.20% (48.15%)</td>
</tr>
</tbody>
</table>

¹) includes all firms
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

- Explore the forms of innovation and combinations (eight exclusive combinations (Wijk))

Table 2: Descriptive statistics of forms of innovations and the eight exclusive associated combinations

<table>
<thead>
<tr>
<th>Innovation Type</th>
<th>Pooled</th>
<th>UK</th>
<th>France</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product innovation</td>
<td>2646 (50.74%)</td>
<td>994 (49.35%)</td>
<td>1652 (51.61%)</td>
</tr>
<tr>
<td>Process innovation</td>
<td>3530 (67.69%)</td>
<td>1111 (55.16%)</td>
<td>2419 (75.57%)</td>
</tr>
<tr>
<td>Organizational innovation</td>
<td>3336 (63.97%)</td>
<td>1217 (60.43%)</td>
<td>2119 (66.20%)</td>
</tr>
<tr>
<td>Product innovation only (W100)</td>
<td>374 (7.17%)</td>
<td>192 (9.53%)</td>
<td>182 (5.69%)</td>
</tr>
<tr>
<td>Process innovation only (W010)</td>
<td>637 (12.21%)</td>
<td>229 (11.37%)</td>
<td>408 (12.75%)</td>
</tr>
<tr>
<td>Organizational innovation only (W001)</td>
<td>395 (7.57%)</td>
<td>229 (11.37%)</td>
<td>166 (5.19%)</td>
</tr>
<tr>
<td>Product and process innovation only (W110)</td>
<td>423 (8.11%)</td>
<td>137 (6.80%)</td>
<td>286 (8.93%)</td>
</tr>
<tr>
<td>Product and organizational innovation only (W101)</td>
<td>471 (9.03%)</td>
<td>243 (12.07%)</td>
<td>228 (7.12%)</td>
</tr>
<tr>
<td>Process and organizational innovation only (W011)</td>
<td>1092 (20.94%)</td>
<td>323 (16.04%)</td>
<td>769 (24.02%)</td>
</tr>
<tr>
<td>Both (W111)</td>
<td>1378 (26.42%)</td>
<td>422 (20.95%)</td>
<td>956 (29.87%)</td>
</tr>
<tr>
<td>None (W000)</td>
<td>445 (8.53%)</td>
<td>239 (11.86%)</td>
<td>206 (6.44%)</td>
</tr>
</tbody>
</table>

Sources: CIS 4 (UK and France)
Two approaches for testing complementarities:

- **4.1 Complementarities-in-use:** two sets of activities are linked, the use of one practice often requires the use of other practices (CORR and RED)
- Identify the relatedness in the use of different practices
- Find evidence that some practices are usually combined with others
- Descriptive statistics, trivariate probit, multinominal logit

- **4.2 Complementarities-in-performance:** performance effects of the use of different practices in combination with one another (PROD and SUPERMOD)
- Direct test of the economic value and performance
- Mutual product of the joint use of practices produce economic benefits that are greater than the individual parts
- Heckman OLS regression on labour productivity as a performance function with test of the endogeneity of Wijk for supermodularity tests
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

- Qualitatives Variables: Mathematical concept of lattices

- The theory of supermodularity based on Topkis (1978) lattice theory allows for the discreteness of the factors/strategies, notably taking binary values (present (1), absent (0)).

- **Supermodularity**: performance function \( f(x_1,x_2) \)
- Case of two types of innovation: Product \( x_1 \) and Process \( x_2 \):
  \[
  f(1,1) - f(0,1) > f(1,0) - f(0,0)
  \]

Introducing Product innovation \( x_1 \) is more efficient-productive when Process innovation \( x_2 \) is introduced simultaneously

\( f(x_1,x_2) \) is supermodular

Two practices: only one inequality constraint
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

Case of three types of innovation:

Product (x1), Process (x2) and Organization (x3):

Set of eight exclusive combinations $W_{1i1j1k}$ from W000 to W111 where $1_i=1$ if the firm introduces a product innovation; zero otherwise,

$1_j=1$ if the firm introduces a process innovation; zero otherwise,

and $1_k=1$ if the firm introduces an organizational innovation; zero otherwise

Supermodularity: performance function $f(x_1,x_2,x_3)$

Testing complementarity between Product (x1) and Process (x2)

NOT only one inequality constraint,

but TWO inequality constraints

$f(1,1,0) - f(0,1,0) > f(1,0,0) - f(0,0,0)$ when ORG is absent

$f(1,1,1) - f(0,1,1) > f(1,0,1) - f(0,0,1)$ when ORG is present
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

- Testing complementarity between Product ($x_1$) and Process ($x_2$)
  - NOT only one inequality constraint, but TWO inequality constraints
    - $f(1,1,0) - f(0,1,0) > f(1,0,0) - f(0,0,0)$ when ORG is absent
    - $f(1,1,1) - f(0,1,1) > f(1,0,1) - f(0,0,1)$ when ORG is present
  - Testing substituability is replacing '>' by '<'

- Testing these two inequality constraints together:
  - unconditional complementarity (Kodde & Palm, 1986)
  - but can lead to inconclusive interpretations

- We then introduced a more detailed approach than the literature:
  - Testing these two inequality constraints individually:
    - conditional complementarity
Unconditional complementarity tests (Kodde & Palm, 1986) can lead to inconclusive interpretations.

Appendix 1: Testing complementarity and substituability of the 7 possible cases of interpretation (Kodde-Palm LR tests)

- H0 accepted
- H0 rejected
- Doubt

Critical values for two constraints:
- at 5% level: lower bound (df=1) = 2.706 and upper bound (df=2) = 5.138
- at 1% level: lower bound (df=1) = 5.412 and upper bound (df=2) = 8.273

We accept H0 if LR statistic is smaller than the lower bound. We reject H0 if this LR statistic is larger than the upper bound. If this statistic is between the bounds, the outcome is within the doubt region.
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

- **Unconditional complementarity tests** (Kodde & Palm, 1986) can lead to inconclusive interpretations

<table>
<thead>
<tr>
<th>Case</th>
<th>Test of Supermodularity: Testing for complementarity</th>
<th>Test of Submodularity: Testing for substituability</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H0 accepted</td>
<td>H0 rejected</td>
<td>Strict complementarity (Strict COMPL.)</td>
</tr>
<tr>
<td>2</td>
<td>H0 rejected</td>
<td>H0 accepted</td>
<td>Strict substituability (Strict SUBST.)</td>
</tr>
<tr>
<td>3</td>
<td>H0 accepted</td>
<td>Doubt</td>
<td>Weak complementarity (Weak COMPL.)</td>
</tr>
<tr>
<td>4</td>
<td>Doubt</td>
<td>H0 accepted</td>
<td>Weak substituability (Weak SUBST.)</td>
</tr>
<tr>
<td>5</td>
<td>H0 accepted</td>
<td>H0 accepted</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>6</td>
<td>H0 rejected</td>
<td>H0 rejected</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>7</td>
<td>Doubt</td>
<td>Doubt</td>
<td>Inconclusive</td>
</tr>
</tbody>
</table>
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

- Case of **three types of innovation**: Product (x1), Process (x2) and Organization (x3)

- Testing **unconditional** and **conditional** complementarity between Product (x1) and Process (x2):

  - Two inequality constraints:
    - When Organization (x3) is absent (Org=0)
    - When Organization (x3) is present (Org=1)
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

- Testing for the THREE couples (pair-wise tests):
  - Product and Process
  - Product and Organization
  - Process and Organization

- Testing SIX inequality constraints
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

**Results: Complementarities-in-use**

**Trivariate probit: main results**

- **Size** has a positive effect on **process** and **organizational** innovations, no effect on **product** (economies of scale)

- **Internal R&D** has a positive effect on **product innovation**, negative on process for FR, and positive on organizational innovation in UK only

- **Training** has no effect on product, and a positive effect on process and organizational innovations.

- **Cooperation, openness** have always a **positive** effect

- **Informal appropriability** has always a **positive** effect, confirming many enquiries about its higher protection than formal protection.
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

**Trivariate probit:** similarities and differences between Countries

- **UK:** complementarity between process and organizational innovation
  - and also between product and organizational innovation
  - no relation between product and process innovation

- **France:** complementarity between process and organizational innovation
  - no relation between product and organizational innovation
  - substitution between product innovation and process innovation

<table>
<thead>
<tr>
<th>Correlations of residuals</th>
<th>UK</th>
<th>France</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Product / Process</td>
<td>0.019</td>
<td>0.54</td>
<td>-0.062**</td>
</tr>
<tr>
<td>Product / Organization</td>
<td>0.079**</td>
<td>2.12</td>
<td>0.034</td>
</tr>
<tr>
<td>Process / Organization</td>
<td>0.185***</td>
<td>4.96</td>
<td>0.265***</td>
</tr>
</tbody>
</table>

Sources: CIS 4 (UK and France), Industry dummies are not reported. Significance levels at *** 1%, ** 5% and * 10%.
Multivariate probit: eight exclusive innovation combinations (Wijk)

- The number of significant factors increases in the number of different forms of innovation done simultaneously
- Firms need a more systematic use of the diverse possible strategies when the aim is innovation in all forms
  - Size becomes a positive factor only when the firm innovates in the 3 forms
  - R&D is the most often positive & significant factor, except for process only
  - Training always increases innovation except when there is only product innovation, (or Prod combined with Org in UK)
  - Cooperation always enhances the probability of innovation mainly in UK, but less in France
  - Sources (Openness): positive only when Org Innov
  - Intellectual protection, formal or not, increases the probability of innovating, although much less in UK
  - Financial, knowledge and market obstacles to innovation no influence, except financial in UK
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

Results: Complementarities-in-performance

Performance is regressed on the eight combinations of innovations and control variables

Table 3: Exclusive innovation combinations and performance. Dependent variable: Log of sales per employee (2004 in Euro)

<table>
<thead>
<tr>
<th></th>
<th>UK Coef.</th>
<th>z</th>
<th>France Coef.</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>W000</td>
<td>0.843***</td>
<td>7.71</td>
<td>0.758***</td>
<td>5.35</td>
</tr>
<tr>
<td>W100</td>
<td>0.813***</td>
<td>7.45</td>
<td>0.723***</td>
<td>5.16</td>
</tr>
<tr>
<td>W010</td>
<td>0.876***</td>
<td>7.97</td>
<td>0.759***</td>
<td>5.23</td>
</tr>
<tr>
<td>W001</td>
<td>0.866***</td>
<td>7.80</td>
<td>0.734***</td>
<td>5.16</td>
</tr>
<tr>
<td>W110</td>
<td>0.903***</td>
<td>8.00</td>
<td>0.773***</td>
<td>5.33</td>
</tr>
<tr>
<td>W101</td>
<td>0.878***</td>
<td>8.00</td>
<td>0.789***</td>
<td>5.47</td>
</tr>
<tr>
<td>W011</td>
<td>0.880***</td>
<td>8.07</td>
<td>0.758***</td>
<td>5.31</td>
</tr>
<tr>
<td>W111</td>
<td>0.886***</td>
<td>7.93</td>
<td>0.775***</td>
<td>5.43</td>
</tr>
</tbody>
</table>
Results: *Complementarities-in-performance*

- **Size** has no influence

- **R&D** has a positive effect on performance, which can be interpreted as an “absorptive capacity” effect (Cohen-Levinthal, 1990) since innovations are controlled for

- **Financial** and **knowledge obstacles** have the right negative sign but are significant only for France, while the **market obstacles** are always significant (less rent from innovations)

- **Appropriability methods** have no effect on performance, but these have normally been captured in the innovation equations
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

*Unconditional complementarity tests* (Kodde & Palm, 1986) lead *mostly to inconclusive interpretations*

- Only two cases of conclusive interpretations

<table>
<thead>
<tr>
<th></th>
<th>UK</th>
<th>France</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supermodularity</td>
<td>1.108*** (H0 accepted)</td>
<td>0.977*** (H0 accepted)</td>
</tr>
<tr>
<td>Submodularity</td>
<td>0.008*** (H0 accepted)</td>
<td>0.610*** (H0 accepted)</td>
</tr>
<tr>
<td>PROD / PROC</td>
<td>Inconclusive</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>Supermodularity</td>
<td>0.622*** (H0 accepted)</td>
<td>1.873*** (H0 accepted)</td>
</tr>
<tr>
<td>Submodularity</td>
<td>0.145*** (H0 accepted)</td>
<td>0.000*** (H0 accepted)</td>
</tr>
<tr>
<td>PROD / ORG</td>
<td>Inconclusive</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>Supermodularity</td>
<td>0.000*** (H0 accepted)</td>
<td>0.222*** (H0 accepted)</td>
</tr>
<tr>
<td>Submodularity</td>
<td>2.251*** (H0 accepted)</td>
<td>1.622*** (H0 accepted)</td>
</tr>
<tr>
<td>PROC / ORG</td>
<td>Inconclusive</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>5%</td>
<td>Lower bound : 2.706</td>
<td>Upper bound : 5.138</td>
</tr>
</tbody>
</table>
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

**Unconditional complementarity tests** by sub-samples:

- Lead mostly to inconclusive interpretations
- Only two cases /24 of conclusive interpretations

- SME: all tests are inconclusive
- Large firms: week substituability between PROC / ORG in UK
- Low R&D: all tests are inconclusive
- High R&D: all tests are inconclusive

- We then implement a more detailed approach than the literature: *Conditional complementarity*
Conditional complementarities comparing France and UK:

- Similar results on *conditional complementarities* between product and process when organizational innovation is absent.
- Only for French firms, product and organizational innovations are *conditional complements* when firms do not introduce process innovation.
- *Conditional substitution* effect in both countries between process and organization when product is introduced.
First lessons comparing France and UK:

1. **French firms** can only choose between **two strategies** - “technological strategy” (Product-Process) and “structure oriented strategy” (Product-Organization), but the estimated returns are likely to be higher for none of the two. **UK firms** must choose the “technological” (Product-Process) strategy.

2. Strategies are then **Country dependent**. Contingency theory applies: there is **no unique best strategy**

   *Strong strategic implications* for French and UK managers

4. This suggests further **sample splits**
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

Sample split according to size: small-medium versus large firms
4. The Fateful Triangle: Complementarities in Performance between Product, Process and Organizational Innovation

Sample split on “capabilities”: high-tech / low-tech firms
Lessons from the size split:

- **SMEs** have to choose clearly between the "technological strategy" and the "structure-oriented strategy", for cost reasons.

- Large UK firms should choose a **product-process-organization strategy** benefiting from economies of scale.

Lessons from the “capabilities” split:

1. **High Tech firms** benefit more from complementarities than Low Tech firms: logical in the context of the competition by innovation.

2. French firms and UK firms should choose different strategies:
   - “Structure oriented strategy” (Product-Organization) for French firms
   - “Technological strategy” (Product-Process) for UK firms
Gracias por su atención
Thanks for your attention

Muy bien venidos a Dijon!
Your are more than welcome to come to Dijon!

Preguntas? Comentarios?
Questions? Comments?

Fabrice.Galia@bsb-education.com
The Process of Innovation: Obstacles and Complementarities

Fabrice GALIA
Burgundy School of Business - BSB
CEREN - Dept. of Organisation Management and Entrepreneurship
Chair MIR - Management and Responsible Innovations
Chair Corporate Governance
Fabrice.Galia@bsb-education.com

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