UNIVERSITE LIBRE DE BRUXELLES
Faculté des Sciences Sociales, Politiques et Economiques
SECTION DES SCIENCES ECONOMIQUES

Année Académique 1997-1998

ECONOMIC AND TECHNOLOGICAL PERFORMANCES OF INTERNATIONAL FIRMS

Thèse présentée en vue de l’obtention du grade de
Docteur en Sciences Économiques par
Michele CINCERA
Membres du Jury

Directeur de Thèse: Mr. Henri CAPRON (*Université Libre de Bruxelles*)

Jury restreint:
Mme Marie-Christine ADAM (*Université Libre de Bruxelles*)
Mme Bronwyn HALL (*Université de Berkeley*)
Mr. Jacques MAIRESE (*CREST-INSEE*)
Mme Françoise THYS-CLEMENT (*Université Libre de Bruxelles*)
Mr. Luc WILKIN (*Université Libre de Bruxelles*)
**Acknowledgements**

I would ask a number of people to accept my most sincere thanks for their support and assistance in carrying out this research project. First of all, I want to express my gratitude to my supervisor, Professor Henri Capron. Not only is he at the root of my interest in this exciting and burgeoning literature on the relation of the growth of knowledge to economic development, but he also continually heartened my efforts to grasp this field more deeply. I owe a lot to him for his training and immense availability and I wish to emphasize his remarkable qualities as a man and as a supervisor. I also wish to express my thanks to my colleague, but friend in the first place, Bruno Van Pottelsberghe. Our work in related research areas is the root of uninterrupted emulation and invaluable externalities. I am also particularly grateful to Professor Bronwyn Hall for having accepted to supervise my research throughout the Thesis and especially during the last term of 1995 at Berkeley University. I never will forget her enthusiasm, encouragement, guidance and always stimulating correspondence. I am also indebted to Professor Jacques Mairesse who gave me the opportunity to visit CREST-INSEE in November 1996. His useful comments and suggestions have substantially improved the final version of a paper based on Chapter 6 and forthcoming in Annales d’Economie et de Statistiques. This work has been achieved in an ideal setting provided by the inspiring atmosphere at CREST. Financial support of Université Libre de Bruxelles, Fonds National de la Recherche Scientifique, British Council and CREST-INSEE is gratefully acknowledged.

Many people have contributed to this work. I am deeply indebted to many professors and colleagues from the Department of Economics at Université Libre the Bruxelles for their many constructive criticisms during the course of the Thesis. Parts of this work have been presented and discussed at several seminars and congresses. Earlier versions of Chapter 4 have benefited from very illuminating comments and suggestions received from participants of the 7th Econometric Society World Congress held in Tokyo in August 1995, the 6th Biennial International Conference on Panel Data held in Amsterdam in June 1996, as well as seminars at University of Aarhus and Hong Kong University of Science and Technology. On Chapter 6, valuable remarks were received from participants of the International Conference on “The Economics and Econometrics of Innovation” held in Strasbourg in June 1996 and the OECD conference on “Science-based Economy Indicators” held in Paris in June 1996, as well as seminars at Université Libre de Bruxelles and CREST-INSEE. Some chapters of the Thesis have been submitted for publication and have benefited from referee reports which led to considerable improvements of some of the ideas and methodology developed in this research. In particular, I want to thank Professor Trivedi of Indiana University for his support and help during the several revisions of my published paper in the Journal of Applied Econometrics. I also wish to acknowledge Marjorie Gassner, Maria Jepsen and Pénélope Papandropoulos who provided invaluable help in carefully examining the drafts of the Thesis for typographical errors and grammatical mistakes. Finally, I want to express my deepest and most heartfelt gratefulness to my friends, my parents, my sister and my companion for their patience, understanding and moral support over the many years this research has taken.

My thanks to all of the above, and to all the other people who have been willing to talk with me during this undertaking.
# CONTENTS

*Acknowledgements*  
*Contents*  
*List of Tables*  
*List of Figures*  

## I. INTRODUCTION  
1. **THE CONTEXT**  
2. **RESEARCH OBJECTIVES OF THE THESIS**  
3. **OUTLINE OF THE THESIS**  

## II. TECHNOLOGICAL ACTIVITIES OF FIRMS: DEFINITIONS AND CONCEPTS  
2.1. **INTRODUCTION**  
2.2. **FACTS ABOUT FIRMS’ TECHNOLOGICAL ACTIVITIES**  
2.3. **TECHNOLOGICAL CHANGE: CONCEPTS AND DEFINITIONS**  
   2.3.1. Process of Technological change  
   2.3.2. Scope of R&D activities  
2.4. **DETERMINANTS OF TECHNOLOGICAL CHANGE**  
   2.4.1. Knowledge production and market failures  
   2.4.2. Role of firm and industry characteristics upon innovation  
   2.4.3. Rivalry and strategic technological competition  
   2.4.4. Public S&T policies and technological change  
2.5. **OUTCOME OF TECHNOLOGICAL CHANGE**  
2.6. **CONCLUSION**  

## III. THE LARGE INTERNATIONAL TECHNOLOGY ENTERPRISES (LITE) DATABASE  
3.1. **INTRODUCTION**  
3.2. **DESCRIPTION OF THE LITE DATABASE**  
   3.2.1. Database content and variables definition  
   3.2.2. Database structure, reliability and representativeness  
3.3. **PATENTS**  
   3.3.1. Source, strengths and weaknesses of patent data  
   3.3.2. Matching of patents to firms and IPC classes  
3.4. **CONSTRUCTION OF VARIABLES**
### Contents

3.5. COMPOSITION OF SUB-SAMPLES 60
  3.5.1. Cleaning procedure 60
  3.5.2. Balanced sample 61
  3.5.3. Large sample 64
  3.5.4. Long sample 66

3.6. CONCLUSION 69

IV. PATENTS, R&D AND TECHNOLOGICAL SPILLOVERS AT THE FIRM LEVEL: SOME EVIDENCE FROM ECONOMETRIC COUNT MODELS FOR PANEL DATA 70

4.1. INTRODUCTION 71

4.2. PATENT-R&D SPECIFICATION AND COUNT MODELS FOR PANEL DATA 73
  4.2.1. The Knowledge Production Function and the Basic Poisson Model 73
  4.2.2. Negative Binomial and GEC Models 76
  4.2.3. PML, QGPML and SML estimators 78
  4.2.4. CML Estimators 81
  4.2.5. GMM Estimators 82
  4.2.6. Dynamic specification 84

4.3. PATENT AND R&D: REVIEW OF THE EMPIRICAL LITERATURE 85

4.4. EMPIRICAL FINDINGS 93
  4.4.1. Basic OLS results and ML estimators 93
  4.4.2. PML and SML estimators 96
  4.4.3. Conditional Poisson and GMM estimators 97
  4.4.4. Testing for exogeneity of regressors and serial correlation 100

4.5. CONCLUSION 102

V. COMPARING THE CONTRIBUTION OF RESEARCH AND DEVELOPMENT TO PRODUCTIVITY GAINS OF INTERNATIONAL MANUFACTURING FIRMS 104

5.1. INTRODUCTION 105

5.2. PRODUCTION RESIDUAL METHODOLOGY AND ECONOMETRIC FRAMEWORK 107
  5.2.1. Production function framework 107
  5.2.2. Econometric estimation methods 111

5.3. THE R&D CONTRIBUTION TO FIRMS’ PRODUCTIVITY: REVIEW OF SOME SELECTED STUDIES 116

5.4. MAIN RESULTS OF THE R&D CONTRIBUTION TO PRODUCTIVITY 126
  5.4.1. R&D and productivity: basic results 127
  5.4.2. R&D and productivity: alternative specifications 129
  5.4.3. R&D and productivity: estimates by industry, geographic area, firm’s size, R&D intensity and time period 140
  5.4.4. R&D and productivity: simultaneity of the R&D decision 148

5.5. CONCLUSION 152
### VI. EXPLORING THE SPILLOVER IMPACT ON PRODUCTIVITY OF WORLD-WIDE MANUFACTURING FIRMS

**VI.1. INTRODUCTION**

**VI.2. R&D SPILLOVERS: REVIEW OF THE LITERATURE**
- VI.2.1. Formalizing and measuring R&D spillovers
- VI.2.2. Review of selected econometric studies at the micro level

**VI.3. LOCATING FIRMS INTO THE TECHNOLOGICAL SPACE**
- VI.3.1. Technological and geographical opportunities and market factors
- VI.3.2. Technological proximities and R&D spillovers
- VI.3.3. Firm’s attribution to technological clusters
- VI.3.4. Distortions into the technological space and alternative technological distance measures

**VI.4. DATA, PRODUCTIVITY EQUATIONS AND ECONOMETRIC FRAMEWORK**

**VI.5. EMPIRICAL RESULTS**
- VI.5.1. Basic results
- VI.5.2. Estimates by geographic area
- VI.5.3. Comparison with other studies
- VI.5.4. Robustness of spillover variables

**VI.6. CONCLUSION**

### VII. CONCLUSION

**VII.1. LESSONS FROM FIRMS TECHNOLOGICAL AND ECONOMIC PERFORMANCES**

**VII.2. SUGGESTIONS FOR FUTURE RESEARCH**

REFERENCES

APPENDICES
LIST OF TABLES

Table 2.1  R&D indicators for the Triad 15
Table 2.2  Top 20 R&D firms in the LITE database, 1994 16
Table 2.3  Effectiveness of alternative methods of learning about new processes and products 23
Table 2.4  Public financed R&D performed in industry and public labs 24
Table 3.1  Variable list sorted by category of information 43-44
Table 3.2  Definitions of variables in the LITE database 44-45
Table 3.3  Data availability of firms in the LITE database 47
Table 3.4  Geographic and sectoral breakdown of firms in the LITE database 47
Table 3.5  Representativeness of net sales as percent of GDP 48
Table 3.6  Representativeness of R&D expenses 48
Table 3.7  Sampling distribution of the shares of sales performed in the home country 58
Table 3.8  List of constructed variables 59
Table 3.9  Number of firms removed by application of the cleaning criteria 61
Table 3.10  Sectorial and geographical characteristics of variables - Sample S625 62
Table 3.11  Representativeness of S625 63
Table 3.12  Descriptive statistics of S625 64
Table 3.13  Sectorial and geographical characteristics of variables - Sample S2445 65
Table 3.14  Representativeness of S2445 66
Table 3.15  Descriptive statistics of S2445 66
Table 3.16  Sectorial and geographical characteristics of variables - Sample S181 68
Table 3.17  Representativeness of S181 68
Table 3.18  Descriptive statistics of S181 68
Table 4.1  Review of selected studies examining the Patent-R&D relationship at the firm level: study, data and specification 86
Table 4.2  Review of selected studies examining the Patent-R&D relationship at the firm level: econometric models 88
Table 4.3  Review of selected studies examining the Patent-R&D relationship at the firm level: patents as a function of current and lagged values of R&D 90
Table 4.4  Review of selected studies examining the Patent-R&D relationship at the firm level: patents as a function of R&D and spillover stocks 92
Table 4.5  Review of selected studies examining the Patent-R&D relationship at the firm level: dynamic specification of patents 92
Table 4.6  Parameter estimates of the knowledge production function: OLS and ML estimators 95
Table 4.7 Parameter estimates of the knowledge production function: PML and SML estimators 96
Table 4.8 Parameter estimates of the knowledge production function: Conditional and GMM estimates 98
Table 4.9 LFM model: serial correlation test 100
Table 4.10 Strict versus weak exogeneity of instruments 101
Table 4.11 Restricted versus non restricted serial correlation 101
Table 5.1 Selected Productivity-R&D studies at the micro level: elasticity of R&D, level dimension 120
Table 5.2 Selected Productivity-R&D studies at the micro level: elasticity of R&D, temporal dimension 123
Table 5.3 Selected Productivity-R&D studies at the micro level: rates of return to R&D 125
Table 5.4 Elasticity of R&D, balanced sample 128
Table 5.5 Elasticity of R&D, large sample 130
Table 5.6 Rates of return to R&D 131
Table 5.7 Net plant, property and equipment versus accumulated sum of current and past (depreciated) capital expenses 135
Table 5.8 Alternative price deflators 136
Table 5.9 Time trend 137
Table 5.10 Returns to scale 138
Table 5.11 Industry and geographic effects 140
Table 5.12 Estimates by industry sector 141-142
Table 5.13 Estimates by geographic area 143
Table 5.14 Estimates by firm’s size 145
Table 5.15 Estimates by R&D intensiveness 146
Table 5.16 Estimates by yearly cross-section time period 147
Table 5.17 Estimates by 4-years time sub-period 148
Table 5.18 Dating of physical capital 149
Table 5.19 GMM estimates and simultaneity 150
Table 6.1 Summary of econometric studies assessing the impact of spillovers on firms’ economic performances 164-165
Table 6.2 Example of technological proximity between firms 173
Table 6.3 Technological proximities within and across industries 174
Table 6.4 Clustering partial results: inertia ratio 177
Table 6.5 Productivity estimates: basic results 183
Table 6.6 Productivity estimates: opportunity effects 184
Table 6.7 Productivity estimates by geographic area 186
Table 6.8 Productivity estimates: comparison with Jaffe (1988) 188
Table 6.9 Productivity estimates: comparison with Los and Verspagen (1996) 189
Table 7.1 Main results in a nutshell: is R&D worth the time and effort involved? 200
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Structure of the Thesis</td>
<td>6</td>
</tr>
<tr>
<td>2.1</td>
<td>Trends in business-funded R&amp;D as a percentage of GDP in 6 OECD countries: 1981 to 1993</td>
<td>13</td>
</tr>
<tr>
<td>2.2</td>
<td>Trends in business R&amp;D personnel in 5 OECD countries: 1981 to 1992</td>
<td>13</td>
</tr>
<tr>
<td>2.3</td>
<td>Trends in Inventiveness (log resident patent applications per 10000 habitants) in 5 OECD countries: 1981 to 1992</td>
<td>14</td>
</tr>
<tr>
<td>2.4</td>
<td>Distribution of Innovation Expenses in 1992 in some Member State</td>
<td>22</td>
</tr>
<tr>
<td>2.5</td>
<td>Importance of the objectives of Innovation (Percentage of firms considering these factors as very important or essential (1990-1992))</td>
<td>25</td>
</tr>
<tr>
<td>2.6</td>
<td>Importance of factors hampering innovation</td>
<td>26</td>
</tr>
<tr>
<td>2.7</td>
<td>Determinants &amp; outcomes of technological activities</td>
<td>40</td>
</tr>
<tr>
<td>3.1</td>
<td>Industry sector based distribution of the share of sales performed in the firms' home country</td>
<td>58</td>
</tr>
<tr>
<td>5.1</td>
<td>Alternative rates of obsolescence of R&amp;D capital, total estimates</td>
<td>133</td>
</tr>
<tr>
<td>5.2</td>
<td>Alternative rates of obsolescence of R&amp;D capital, first difference estimates</td>
<td>133</td>
</tr>
<tr>
<td>5.3</td>
<td>Alternative rates of obsolescence of R&amp;D capital, within estimates</td>
<td>133</td>
</tr>
<tr>
<td>6.1</td>
<td>Technological position vector of firms</td>
<td>168</td>
</tr>
<tr>
<td>6.2</td>
<td>Transformed technological proximity: multiplicative function</td>
<td>179</td>
</tr>
<tr>
<td>6.3</td>
<td>Transformed technological proximity: logarithmic reciprocal function</td>
<td>180</td>
</tr>
<tr>
<td>6.4</td>
<td>Clustering partitions, local stock, within estimates</td>
<td>190</td>
</tr>
<tr>
<td>6.5</td>
<td>Clustering partitions, external stock, within estimates</td>
<td>191</td>
</tr>
<tr>
<td>6.6</td>
<td>Multiplicative distortion, first differences estimates</td>
<td>192</td>
</tr>
<tr>
<td>6.7</td>
<td>Multiplicative distortion, within estimates</td>
<td>192</td>
</tr>
<tr>
<td>6.8</td>
<td>Logarithmic reciprocal distortion, first differences estimates</td>
<td>193</td>
</tr>
<tr>
<td>6.9</td>
<td>Logarithmic reciprocal distortion, within estimates</td>
<td>194</td>
</tr>
</tbody>
</table>