CORPUS

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First and foremost, I would like to thank my supervisor, Professor Henri Capron, for his trust since the launching of the Ph.D. proposal in November 1992, and for his enthusiastic encouragement and precious comments. Although I am the only author reported on the cover of this thesis, and I take full responsibility for the views expressed here or any remaining errors, I would like to highlight that the fingerprint of Henri Capron is well anchored in the following pages. His striving for clearness of exposition improved my work considerably.

As extensively elaborated in this thesis, research is a process where externalities are important. I have received many positive externalities from three types of environment: my working environment, two research institutes abroad, and several scientific meetings.

I am indebted to Professor Paul Kestens who helped me in my work by providing the stimulating research environment and the useful infrastructure of the Department of Applied Economics of Université Libre de Bruxelles (DULBEA). Perhaps the most important externalities came from my friend, and then colleague, Michele Cincera. Indeed, we both began a Ph.D. in innovation economics at the same time, and with the same supervisor. Michele Cincera focused on micro-economic aspects of the economic analysis of technological change, whereas I concentrated on industry level analyses. Needless to say, our complementary works induced intense synergies and feedback. I further benefited from the remarks of several professors and researchers at the Université Libre de Bruxelles, especially during two seminars jointly organized by CEME and ECARE in January 1995 and October 1996. Finally, I had the pleasure of working with Arkadi Panitch, who was finishing his Ph.D. in Physics. Our interdisciplinary collaboration took place in the field of the efficiency of government support to R&D.

In addition to these 'local' externalities, I had two opportunities to develop my research skills abroad. The first opportunity came in August 1995, when Professor Hiroyuki Odagiri was willing to act as my host at the Research Institute of the Japanese Ministry of International Trade and Industry (MITI/RI). I am very grateful to Professor Odagiri, as well as to Professor Ryutaro Komya, president of the MITI/RI, for having arranged a four-month position as visiting researcher and for providing me with the necessary operational assistance. During my stay at the Research Institute I began research on interindustry R&D spillovers which, after several months of further analyses at home, led to the completion of Chapter 5. The second opportunity to work abroad came at the beginning of 1996, when Professor Frank Lichtenberg arranged a visiting researcher position at the Columbia Business School. During this four-month collaboration we worked intensely on international R&D spillovers. This investigation of the extent to which knowledge is diffused across countries is at the origin of Chapter 6. Needless to say, I am also very grateful to Professor Lichtenberg for having rendered this research in New York possible.[1]

The ideas and results developed in the chapters of this thesis have been presented in various congresses and seminars. The discussions that took place during these scientific meetings led to useful remarks for my work. The four recent congresses where I received the most valuable

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comments from the participants are the *International Conference on the Economics and the Econometrics of Innovation* held in Strasbourg in June 1996; the OECD *Conference on New Indicators for the Knowledge-Based Economy*, held in Paris in June 1996; the Applied Econometric Association (AEA) *Conference on the Econometrics of Innovation and Patent*, held in Luxembourg in November 1996; and the OECD *Conference on Policy Evaluation in Innovation and Technology*, held in Paris in June 1997.

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SUMMARY

1. Introduction The main objective of the present work is twofold. The first one is to determine whether the manufacturing industries' R&D activities have been associated to similar rates of return in the G7 countries during the eighties. We submit that three factors might potentially explain why R&D outlays can be associated to different degrees of efficiency and, in some cases, why they do not translate into productivity growth. These factors are related to the degree of government interventionism in the financing of R&D projects, to the extent to which knowledge diffuses across industries, and to the extent to which knowledge spills over national borders. The second objective is to test the validity of these explanatory factors. Part I (chapters 2 and 3) focuses essentially on the first objective, Part II (chapters 4 to 6) on the second. Departing from the neoclassical stream of analysis, this work is empirical and comparative in its nature and concern. Its main peculiarities with respect to the existing body of empirical literature are a greater emphasis on several measurement issues and a first allowance for homogeneous international comparison of various impacts and determinants of R&D.

2. State of the art Chapter 2 aims at selecting an empirical model, amongst the many existing possibilities, for the evaluation of the rate of return to R&D. The total factor productivity growth framework is chosen. Although widely used, this empirical approach is subject to series of criticisms related to the implicit hypotheses that have to be imposed. A critical survey of the literature on the relationship between R&D investment and economic performance clarifies a number of empirical issues. Five important observations emerge from this analytical survey. They are mainly related to the advantage of using panel data, to the choice of the parameter to be estimated, to the output proxy, to slight modifications of the empirical model, and to the problem of international comparability. The broad environment of the empirical analysis being set with respect to these unavoidable preliminary choices, there are still myriad of technical and conceptual issues that need to be clarified with respect to the measurement of total factor productivity growth, R&D capital stock, and to the relationship between them. Several tests are suggested in order to ensure the robustness of the estimated rate of return to R&D. Some of them are trivial but might be crucial, such as including industry and time dummies into the regression equation. Others are less trivial but barely used, such as allowing for free returns to scale, correcting for the double counting and expensing of R&D, and relying on a best fitting strategy to determine the most appropriate R&D depreciation rates and lag. Finally, various tests might be seen as pioneering, such as testing for perfect competition, using industry-specific R&D depreciation rates and lag, and mitigating the influence of outlying observations.

3. The rate of return to R&D For each of the G7 countries, the rate of return to total R&D investment is estimated on the basis of a panel data set composed of 22 manufacturing industries analyzed over the eighties. The key empirical results lead to the following conclusions. First, the total factor productivity growth approach is much more robust than it appears at first sight. Indeed, allowing for free returns to scale, imperfect competition, and improperly measured labor cost shares has generally a non significant downward effect on the estimated rates of return to R&D. Similarly, including industry and time dummies, correcting for the double counting and expensing of R&D, and using a more appropriate R&D deflator, does not affect substantially the results. Second, the estimated rates of return to R&D are highly sensitive to the assumed R&D depreciation rates, to the assumed lags, to the presence of a few outlying observations, and to the studied period. However, despite this unsteadiness, the ranking of the estimated parameters across countries stays sufficiently stable. Third, the rates of return to R&D vary substantially across countries. Japan takes the lead, with a return to R&D of about 250%. Then come France and Germany, with an R&D impact of about half the one of Japan. The US and Italy are associated to relatively low returns, whereas no significant impact

of R&D are estimated for Canada and the UK. There are several potential reasons that may explain why the rates of return markedly differ across countries and, overall, why R&D does not always crystallize into productivity growth. The validity of three of them is examined in the subsequent chapters.

4. R&D subsidies Chapter 4 attempts to better understand the interrelations between government R&D, private R&D, and productivity growth. More precisely, the focus is put on two basic questions: *(i)* Do R&D subsidies contribute to improve productivity growth to the same extent that private R&D does? and *(ii)* Do R&D subsidies have an indirect impact on productivity growth, via the stimulation of private R&D investments? In the matter of the first question our quantitative analysis does not validate the suspicious stance taken up in the literature against R&D subsidies. Highly subsidized industries benefit from higher returns to total R&D than lowly subsidized industries, probably because of the strong interfirm R&D externalities induced by government interventionism. Further, the rate of return to privately-funded R&D is not significantly higher than the rate of return to publicly-financed R&D. We suggest that disaggregating total R&D into its two main sources of funds is not a reliable approach; mainly because « *a dollar is a dollar, irrespective of source* ». Regarding the second question the econometric results suggest firstly that, at the aggregate industry level, R&D subsidies stimulate private R&D expenditures in the UK, have no effect in the US, Japan, and Germany, and crowd out private R&D in Canada, France, and Italy. Nevertheless, the observed substitution effects are partial: R&D subsidies always contribute to raise total R&D investments. Moreover, in all countries, R&D subsidies foster private R&D investment in some industries. Second, subsidizing an industry might stimulate its own private R&D investment but can also inhibit the R&D investment in other closely related industries. Third, the more a subsidization policy is unstable, the less an increase in R&D subsidies is likely to stimulate private R&D investors. According to this fourth chapter, we have to disregard the idea that the inverse relationship observed between a country's rate of return to R&D and its subsidization rate is due to a weak effectiveness of government R&D.

5. Interindustry R&D spillovers Low returns to direct R&D might be compensated by high returns to external R&D. The main purpose of Chapter 5 is to evaluate how interindustry R&D spillovers contribute to improve productivity growth. Given the structure of the data set we adopt a methodology that consists in estimating the impact of a stock of external R&D on productivity growth. This R&D spillover stock, for a given industry, corresponds to the weighted sum of all other industries' R&D capital stocks. The weights might be derived from input-output, technology flows, or technological proximity matrices. From the survey of the literature on R&D externalities, we submit that two issues related to the weighting methodology have first to be clarified. *(i)* What is the likely nature of the spillovers estimated through the three types of weighting matrices? *(ii)* Are there substantial differences across countries for a given type of weighting matrix? The Principal Components and Clustering analyses of the weights pertaining to the various matrices, and the econometric estimates of the returns to outside R&D yield the following conclusions. First, the input-output links profiles characterizing rent spillovers are distinct, on average, from technological proximity links profiles characterizing knowledge spillovers. The technology flows matrices are closer to the concept of rent spillovers than to the concept of knowledge spillovers. However, they are built on the basis of different data sources, number of observations and periods, which means that it is not possible to determine whether their heterogeneity is more virtual than real. Second, the various input-output matrices, which are relatively highly homogeneous, are not similar enough to be used alternatively in different countries. By transitivity, the procedure, regularly applied in the literature, that consists in using a single technology flows matrix for different countries, is not reliable. Third, it seems that the social rates of return to R&D differ substantially across countries and industries according to the transmission channel considered. Important social returns take place in all countries, but it cannot be inferred that they are the cause of, or compensate for, weaker returns to direct R&D.

6. International R&D spillovers In this chapter, the objective is to evaluate the direction and the effectiveness of three potential channels of international technology transfer: trade, inward FDI, and outward FDI as a proxy for technology sourcing practices. As opposed to the previous chapters, data at the macro level are used. Our objective is to be seen as a pioneering analysis for two reasons. First, we reconcile in some way the literature on international R&D spillover with the literature on the impact of inward FDI by properly incorporating a technological component into FDI flows. Second, it is the first evaluation of the extent to which outward FDI may contribute to improve the home country's productivity through the sourcing of the host countries' technological base. The empirical analysis leads to the following conclusions. First, in re-examining Coe and Helpman's (1995) analysis we find that their methodology can be improved upon by correcting for an aggregation bias and an indexation bias. We provide a more accurate - both theoretically and empirically - model of how the R&D performed by other countries may affect domestic output and productivity via trade flows. However, we confirm that the more a country is open to trade, the more it is likely to benefit from foreign R&D. Second, we give credence to the hypothesis of technology sourcing associated with MNEs' activities abroad. This 'technological boomerang' feature associated with outward FDI emerged mainly during the eighties. Contrary to the frequent conjectures, inward FDI flows do not seem to contribute to the improvement of the technological base in the host economies. Third, our results corroborate that the US is an important R&D spillover-generator but a weak spillover-receiver. On the other hand, Japan contributes to international output growth only through its exports, but there is no R&D spillovers emanating from outward FDI directed towards Japan. This last chapter provides some explanation for the observed paradox concerning the link between R&D and productivity growth. Japan, Germany, and France enjoy relatively high returns to their own R&D activities, as compared to the US and the UK, which contribute much more than the others to international output growth, especially through the technology sourcing channel.

7. Concluding remarks Chapter 7 underlines the common drawbacks of our empirical analyses and puts forward open fields for further research. In spite of the need to extend further these economic analyses, several policy issues emerge. First and foremost, R&D activities seem 'only' to be a necessary (not sufficient) condition for productivity growth, but they might be a sufficient condition against a productivity deterioration. Second, since R&D subsidies are always associated to a rise in total R&D investments, we are more inclined to support the idea that such subsidies are worthwhile, although their effectiveness might be improved upon. For instance, through stable policies and a clear identification of the potential negative interindustry effects of direct subsidies. These indirect effects should be properly identified since they might have a clear incidence on the resources allocation profiles adopted by public authorities. Third, the noticeable impact of interindustry R&D spillovers should also be taken into account when evaluating the effectiveness of government support to R&D. The private and social returns to R&D ought to be confronted to the forgone $ of subsidy for a proper evaluation. In this respect, efficient financial incentives would target the R&D projects implemented by the industries that generate relatively high R&D spillovers and that benefit from weak externalities. Governments, by attempting to correct for market failure, might themselves be subject to failures. These arguments do not dismiss the necessity of government support to business R&D, but they have to be taken as a warning against inadequate policies. Fourth, government policies supporting the adoption and utilization of foreign technologies are likely to yield a high social payoff. The research activities of foreign firms and foreign nations clearly need to be monitored more carefully through active participation in such activities and continual scanning of scientific and technological horizons. In this respect, one appropriate policy, though *a priori* counterintuitive, would aim at fostering investment abroad.

TABLE OF CONTENT

PART II

LIST OF FIGURES

LIST OF TABLES

LIST OF CHARTS