UNIVERSIDAD COMPLUTENSE DE MADRID

FACULTAD DE CIENCIAS ECONÓMICAS Y EMPRESARIALES
Departamento de Fundamentos del Análisis Económico I

COOPERATION IN INNOVATIVE ACTIVITIES, ORGANIZATIONAL INNOVATION AND PRODUCTIVITY: THREE ESSAYS ON ECONOMICS OF INNOVATION

MEMORIA PARA OPTAR AL GRADO DE DOCTOR

PRESENTADA POR

Alberto López Sebastián

Bajo la dirección del doctor
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TESIS DOCTORAL PARA OPTAR AL TÍTULO DE DOCTOR POR LA UNIVERSIDAD COMPLUTENSE DE MADRID

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INTRODUCTION

Innovation activities performed by firms and their economic impacts are of central interest to economists and policy-makers. Analysis of these issues requires both knowledge of the factors that affect firms' ability to innovate and knowledge of the impact of innovation activities on firm performance through changes in both demand and costs.

This dissertation studies two of the most relevant research issues on Economics of Innovation: (i) cooperation in innovative activities, and (ii) the relationship between innovation and productivity. In doing this, I use data at the firm level from the Third Community Innovation Survey (CIS3) and from the Encuesta sobre Estrategias Empresariales (ESEE). The Community Innovation Surveys take place every 4 years in European countries to investigate innovation activities performed by firms. In 2001, the third wave was conducted and covered the period 1998 to 2000. The ESEE is an unbalanced panel survey of Spanish manufacturing firms with 10 or more workers, starting in 1990 and sponsored by the Ministry of Industry. A detailed description of these surveys can be found in each chapter.

This introduction is organized in three parts. Firstly, I introduce the two issues at stake: cooperation in innovative activities and the relationship between innovation and productivity. I focus on contextualizing both topics in the current development of literature on innovation, as well as on specifying my contributions to this literature. Secondly, I present the structure of the dissertation, summarizing the contents of each chapter. Finally, the last part of this introduction is concerned with the main policy implications of the issues covered by this dissertation.

Issues at stake

Cooperation in innovative activities

The innovative activities of a firm partly depend on the variety and structure of its links to sources of information, knowledge, technologies, and human and financial resources. Each of these links connects the innovating firm with other actors in the innovation system: commercial laboratories, universities, policy departments, regulators, public research institutes, competitors, suppliers, and customers. These flows of knowledge between firms and other organisations have an important role in both the development and diffusion of innovations.

The Oslo Manual (OECD, 2005) identifies three types of external linkages: (i) open information sources, (ii) acquisition of knowledge and technology, and (iii) cooperation in innovative activities. Firstly, open information sources provide openly available information that does not require the purchase of technology or intellectual property rights, or interaction with the source. Secondly, acquisition of knowledge and technology are purchases of external knowledge and capital goods (machinery, equipment, software) and services embodied with new knowledge or technology that do not involve interaction with the source. Thirdly, cooperation in innovative activities is active cooperation with other actors in the innovation system (for example, universities, firms or public research institutes) with the objective of performing innovation activities. These activities constitute agreements by which firms share the costs and returns of innovative projects, sometimes with other firms and sometimes with research institutions. In what follows, I focus on this type of external linkage.

With the ultimate interest of stimulating innovation, a lot of attention has recently been paid to the subject of cooperative innovative activities among firms (see, among others, Dodgson (1994), Hagedoorn et al. (2000), Hagedoorn (2002), and Tyler and Steensma (1995)).

Moreover, an important feature of this kind of cooperative activity is its interactions with competition policy. Since the seminal work by Schumpeter (1943), the relationship between market competition and innovation has been a question of interest for economists and policy-makers. Competition heavily influences the way technology and innovation are started and diffused, and the analysis of the dynamics of technology is one of the most important parts of this broad area of interest.

Economic analysis suggests the existence of several difficulties for the innovative activities to be carried out at an optimal level in a fully competitive environment[1]. The character of

[1]See Martin (2002, Chapter 14). This author ,after reviewing the literature, observes that a market

the input "knowledge" (freely usable when displayed), the presence of important fixed -and often sunk- costs associated with innovative activity investments, and the uncertainty associated with the results coming out of these activities are likely to provide few incentives to firms to allocate enough resources to an activity that shows important positive externalities towards other firms and consumers. But, at the same time, as many empirical studies have shown[2], competitive pressure seems in many circumstances to strongly stimulate innovative activities and the introduction of innovations by firms[3].

In this context, cooperation in innovative activities, from a positive point of view, is likely to show mechanisms by which firms can profitably appropriate free flows of knowledge and protect them. Hence, these agreements are an interesting guide to normative regulation, which must try to consolidate mechanisms of incentives and at the same time avoid harming market competition.

To sum up, cooperative innovative activity summarizes many of the questions at stake in the economics of innovation literature, such as, "appropriability", spillovers, the relative roles of rivalry and cooperative outcomes, influence and role of public policy. Therefore, it is a topical policy issue, in the context of technology transfer (most prominently from universities to business), and in its interactions with competition policy. Both the OECD and the European Union support the idea of strong industry-science linkages to maximize the returns from both private and public research investments, and recognize a role for policy (OECD (2004a), OECD (2004b), European Commission (2004)).

In this context, it is important to understand which types of firms tend to engage in cooperative innovative activities, the motivations for such activity and whether public policy is effective in increasing collaborative research. The first two chapters of this dissertation

system results in an insufficient level of innovation relative to the second-best optimum. Moreover, theories of industrial organization typically predict that innovation should decline with competition, as more competition reduces the monopoly revenues that reward entry by new successful innovators (see, among others, Dasgupta and Stiglitz (1980), and Aghion and Howitt (1992)).

[2]See Geroski (1995), Nickell (1996), and Blundell, Griffith and Van Reenen (1999).

[3]See Aghion et al. (2005) for recent empirical evidence on an inverted -U relationship between competition and innovation.

present evidence about the determinants of cooperation in innovative activities. The first explores the determinants for the Spanish manufacturing sector, while the second one investigates cooperative innovative activity in four major European countries, France, Germany, Spain and the UK, using internationally comparable firm-level data for manufacturing and service sectors.

Innovation and productivity growth

The poor productivity performance of European countries relative to the US has been an important focus for government policy. In this sense, the "Lisbon Strategy" intends to deal with the low productivity and stagnation of economic growth in the EU. As pointed out by Sapir et al. (2003): "In the EU, there has been a steady decline of the average growth rate decade after decade and per-capita GDP has stagnated at about 70% of the US level since the early 1980s".

In the first three decades after World War II, Europe established an enviable reputation for both high growth and a high level of social protection. The long post-war expansion had been built on the basis of the generalisation of an already mature technological trajectory with well known organisational implications and rapid diffusion of the best practice. In short, Europe was catching up with the US both through investment and factor accumulation, and through imitation of leading-edge technologies.

In this sense, Sapir et al. (2003) emphasizes the fact that post-war growth in Europe was largely based on imitation and driven by capital accumulation. Europe's unsatisfactory growth performance during the last few decades is a symptom of its failure to transform into an innovation-based economy. A system built around the assimilation of existing technologies, mass production generating economies of scale, and an industrial structure dominated by large firms with stable markets and long term employment patterns no longer delivers in the world of today, characterised by economic globalisation and strong external competition (Sapir et al. (2003)).

What is needed now for European countries is to shift towards growth-based on innovation. Once European countries had moved closer to the technology frontier and also with the occurrence of new technological revolutions in communication and information, growth was driven to a greater extent by innovation and fast adaptation to technical progress. Innovation influences firm performance through a variety of channels that range from the effects of innovation on sales and market shares to changes in productivity and efficiency. Furthermore, important impacts of innovation at industry and national levels are, among others: changes in international competitiveness and in total factor productivity, emergence of knowledge spillovers of firm-level innovations, and an increase in the amount of knowledge flows through networks.

Academics and policy-makers have emphasised the importance of investment in research and development (R&D) as a contributor to long-term productivity growth. Regarding academic literature on this issue, since Griliches (1979), many empirical studies have focused on the link between R&D and productivity[4] and on the role of technological process and product innovations as productivity shifters[5]. In response to these concerns, the European Union has set itself the target of increasing R&D expenditure to 3% of the GDP by 2010 (this is part of the "Lisbon Strategy").

However, a framework broader than technological product and process innovation is needed. In this sense, the third edition of the Oslo Manual (OECD, 2005) expands the definition of innovation to include, besides product and process innovations, two additional types of innovations, organisational innovation and marketing innovation. Including marketing and organisational innovations gives a more complete framework that is better able to capture the changes that affect firm performance and contribute to the accumulation of knowledge.

The third chapter of this dissertation contributes to the literature on innovation and productivity by analyzing the effect of organizational innovation on productivity. An organisational innovation (see OECD, 2005) is the implementation of a new organisational method. These can be changes in (i) a firm's business practices (i.e., the implementation of new methods for organising routines and procedures of the conduct of work), (ii) workplace

[4] See Griliches (1995) for a survey.

[5] Crépon et al. (1998) propose a structural model that describes the link between R&D expenditure, innovation output and productivity.

organisation (i.e., the implementation of new methods for distributing responsibilities and decision-making autonomy among employees, for the division of work as well as new concepts for the structuring of activities), or (iii) external relations (i.e., the implementation of new ways of organising the relations to other firms or public institutions).

Changes in organisational methods can improve the efficiency and quality of firms' operations, thereby increasing demand or reducing costs. There are an increasing number of studies that suggest a significant and positive effect of various measures of organizational innovation on productivity. For example, one of the most significant findings on the relationship between organizational innovation and growth is given by Black and Lynch (2004). These authors find that as much as 30 percent of output growth from 1993-1996 in US manufacturing might be accounted for organizational practices (specifically for workplace practices and re-engineering efforts).

The third chapter focuses on the role of one of the most relevant organizational methods, outsourcing. In this sense, the third edition of the Oslo Manual (OECD, 2005) considers "outsourcing or subcontracting of business activities in production, procuring, distribution, recruiting and ancillary services" a new organisational method in a firm's external relations.

Structure of the dissertation

The dissertation is organized in three chapters. The first chapter explores the determinants of R&D cooperation using a sample of Spanish manufacturing firms. The data used correspond to the Third Community Innovation Survey (CIS3; period 1998-2000), carried out in Spain by the Instituto Nacional de Estadística (INE) under the name Encuesta de Innovación Tecnológica en las Empresas. This chapter focuses on the impact of information flows or spillovers on R&D cooperation, but also explores the role of the traditionally considered factors (firm size, cost and risk sharing, complementarities). The estimation methods used allow testing the endogeneity for the explanatory variables, which in other papers are assumed to be endogenous a priori. I find that the choice of an appropriate "structure" of endogeneity has important consequences for the estimates: only in this case do cost-risk sharing and complementarities have the expected positive effect. I also find that the overall picture of the importance of the explanatory variables depends on the estimation method. In this sense, two-step procedures overestimate the importance of spillovers. With a more efficient procedure, I find that cost-risk sharing is the most important determinant of R&D cooperation in Spain. Finally, the overall results on the importance of spillovers are consistent with the existing literature, but I find that a greater level of legal protection in the industry has a negative effect on R&D cooperation.

Different versions of this study have been presented at the European Summer School on Industrial Dynamics (ESSID) in August 2003, at the VII Encuentro de Economía Aplicada in June 2004, at the 32^{nd} EARIE meeting in September 2005 and at the I Escuela de Economía de la Innovación in July 2006. A version of this chapter has been accepted for publication in the *International Journal of Industrial Organization.*

The second chapter investigates cooperative innovative activity in four major European countries, France, Germany, Spain and the UK, using internationally comparable firm-level data for manufacturing and service sectors. Again, the source of the data is the Third Community Innovation Survey. The chapter examines the roles of knowledge flows, cost- and risk-sharing and public financial support in firms' decisions to collaborate. Results suggest that firms which place greater value on external information flows are more likely to cooperate with the research base than with other firms, and that firms facing appropriability problems are more likely to cooperate with the research base and with upstream and downstream firms than with direct competitors. I find evidence for Spain to suggest that firms collaborate to overcome risks and financial constraints. I also find that receipt of public support is positively related to undertaking collaborative innovation. In line with the focus of policy, this relationship is strongest for cooperation with the research base.

I presented a preliminary version of this chapter at the 33^{rd} EARIE meeting in August 2006. The current version, in collaboration with Laura Abramovsky, Elisabeth Kremp, Tobias Schmidt and Helen Simpson, has been accepted for publication in *Economics of Innovation and New Technology.*

The third chapter is aimed at analyzing the relationship between organizational innovation and productivity. I focus on the role of one of the most relevant organizational methods, outsourcing. Outsourcing is a make or buy decision and implies the modification of the boundaries of the firm. It must be seen as part of the organizational innovation process, carried out in the search for increasing flexibility and efficiency. Specifically, this chapter deals with outsourcing at the firm level and focuses on the role of contracting out of manufacturing activities. To address it, I develop and estimate a simple theoretical framework justifying the addition of outsourcing measures to the specification of a "traditional" production function. The framework developed leads to the estimation of a production function depending on traditional inputs (labor, capital and materials) and an index of production subcontracting. Specifically, both the effect of first-time outsourcing on productivity and the effect of the intensity of production subcontracting can be analyzed.

Using an unbalanced panel of Spanish manufacturing firms from the Encuesta sobre Estrategias Empresariales (ESEE), I find that for manufacturing as a whole, both the outsourcing decision and its intensity have a positive effect on productivity. When analyzing industry level results, I find that outsourcing intensity has a positive effect on productivity, mainly for firms belonging to light industries, while the decision of starting (stopping) outsourcing has the expected positive (negative) effect on productivity.

The simple theoretical framework presented in section 3.2 has shortcomings. These limitations are overcome in the last part of the chapter. In this sense, the third chapter ends with a first attempt at modelling and estimating a more structural framework for the specification of a production function considering the possibility of production subcontracting. This framework allows us to identify two "uses" for labour (labour used "directly" in the production of the final output and labour used in the production of the intermediate input). Results presented in the last section show plausible values for the elasticities of both labour "uses", capital and intermediate consumptions.

Different versions of this study have been presented at the XX Jornadas de Economía Industrial in September 2004, at the 32^{nd} EARIE meeting in September 2005, at the IX Encuentro de Economía Aplicada in June 2006 and at the Fourth CEPR School on Applied Industrial Organisation in May 2007.

Policy implications

Productivity analysis performed at the aggregate level systematically shows a slower growth of the EU economy in the 90's when compared with the US (see, for example, Scarpetta et al. (2000)). This, although particularly strong for certain services sectors that intensively use information telecommunications technologies, has been the cause of greater concern and discussion on the ability of the European economy to develop, diffuse and apply the new technologies, and their capabilities of transforming them into an engine of growth. The "Lisbon Strategy", a policy response to this challenge, embodied a broad set of structural reform targets, with the strategic economic goals of creating the most competitive and dynamic knowledge-based economy by 2010. The development of these policies continues today, being a subject of primary attention. The results of this dissertation, focussed on the understanding of cooperation in innovative activities and the effect of innovation on productivity, have some general implications for these policies.

The premise is, as my results show, that innovative activity enhances productivity. The question is how to reinforce the best realisations of this fact. The research done on innovation and productivity has contributed to the literature by analyzing the effect of a particular form of organizational innovation on productivity.

Cooperation in innovative activities emerges from my results as a way, still very unequally developed across European countries, to face the challenges of technological developments by enhancing profitable innovation. This is a timely subject. Both the OECD and the European Union support the idea of developing stronger industry-science linkages. In this sense, in 2003, the British government conducted a major review of the extent of business-university collaboration, which suggested ways to improve government support for such activity[6]. The UK currently operates a number of schemes aimed at encouraging collaborative innovative activity between businesses and research institutions, and business-to-business linkages. In Germany, a significant amount of public funding for innovative activity is now directed towards research consortia comprising private businesses and scientific research institutions, and policies in France and Spain also emphasise public-private sector collabo-

[6]HM Treasury (2003).

ration[7].

My findings support the idea that both the presence of "incoming spillovers" and the ability to "appropriate" the returns from innovation stimulate cooperation, which means that the enlargement of collaborative practices can strengthen innovation and this can be policy-promoted. In fact, the results already show some positive association between cooperation and public support, which possibly stresses the presence of an already active supporting policy.

[7] See Abramovsky et al. (2004) for a summary for the UK, Fier et al. (2006) for information on the direction of funding in Germany, Acosta and Modrego (2001) for further information for Spain, and MNRT (2005) for further information for France.

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CHAPTER 1. DETERMINANTS OF R&D COOPERATION: EVIDENCE FROM SPANISH MANUFACTURING FIRMS

1.1. Introduction

In the ultimate interest of stimulating innovation, much attention has recently focused on the subject of cooperative firm R&D. These agreements, from the positive point of view, are likely to embody mechanisms by which firms can profitably appropriate free flows of knowledge and protect them. Hence, they are an interesting guide to normative regulation, which must try to consolidate mechanisms of incentives and at the same time avoid harming market competition.

R&D cooperation has thus become a major topic for policy makers. Most E.U. and national public funding for R&D is directed at stimulating cooperation between firms, and between firms and public institutions[8]. The rationale behind this policy is to generate or improve information flows or spillovers between these economic agents, as these spillovers are assumed to essentially lead to more economic growth[9] and a better performance of the national system of innovation.

Given this growing interest, the literature has recently paid attention to the relationship between R&D cooperation activity and spillovers. Cassiman and Veugelers (2002), henceforth CV, find that the firms' external information sources (incoming spillovers) and the flows out of the firms measured by the ability of firms to appropriate the returns from innovation (appropriability) have important and separately identifiable effects on the probability of R&D cooperation. Other works have studied the relationship between spillovers and R&D cooperation; see, for example, Belderbos et al. (2004) for evidence on this rela-

[8] See Acosta and Modrego (2001) for an example of public funding in Spain, and Abramovsky, Harrison and Simpson (2004) for a summary for the UK.

[9] See Griliches (1992) for a survey on the empirical evidence on the relationship between R&D spillovers and growth, and Romer (1990) for a theoretical discussion.

tionship from the Netherlands, and Kaiser (2002a) for evidence from the German service sector.

Besides knowledge flows, the literature has identified three major classes of motives for firms to become involved in R&D cooperation: cost and risk sharing[10], complementarities or skill-sharing[11], and factors related to the absorptive capacity of the firm[12]. Firstly, cooperative R&D agreements may be used by firms to set cost and risk-sharing rules in high-cost and risky settings. Hence, when cost and risk are important innovation hampering factors, firms would tend to make cooperative R&D agreements. Secondly, cooperative R&D is a vehicle for firms to learn skills and capabilities from their partners. As such, the greater the availability of technological know-how within the firm, the more likely it is to have complementarities between partners in a cooperative R&D agreement. Finally, one other determinant that is closely related to knowledge flows and complementarities is the idea of absorptive capacity. A firm's absorptive capacity is derived from its own R&D efforts and is a measure of its ability to benefit from other firms' R&D activity. The higher the absorptive capacity of the firm, the higher the benefits from R&D cooperation.

This chapter develops evidence about the determinants of R&D cooperation using a sample of Spanish manufacturing firms, focusing mainly on the importance of spillovers. The study is based on the model introduced by CV, although it departs from these authors to explore some econometric and substantial issues.

The contribution of this study to the empirical literature on R&D cooperation is three-fold. First, I show that an adequate treatment of endogeneity matters a great deal. I find evidence supporting the existence of an important effect of spillovers on R&D cooperation, although cost and risk sharing is the most important determinant for cooperation in Spain. In obtaining these results, I apply a complete treatment for endogeneity. Two alternative estimation methods are used: Two-stage conditional maximum likelihood (2SCML) and Conditional maximum likelihood (CML). These techniques allow me both to test for the

[10] See, among others, Belderbos et al. (2004), Hagedoorn (1993), Miotti and Sachwald (2003), Tether (2002), Tyler and Steensma (1995).

[11] For example, Hagedoorn (1993), Sakakibara (1997), Tyler and Steensma (1995).

[12] See, among others, Cohen and Levinthal (1989), Röller et al (2002), Sakakibara (1997), Tether (2002).

endogeneity of the explanatory variables which in other papers are assumed to be endogenous a priori and to obtain efficient estimates. I find that the choice of an appropriate "structure" of endogeneity is crucial and has important consequences for the estimates. I also find that, depending on the estimation method, a different picture of the importance of the explanatory variables is obtained. In this sense, two-step procedures overestimate the importance of spillovers and underestimate the impact of cost and risk sharing reasons on the probability of R&D cooperation.

Second, I obtain new insights on the topic due to the sample employed. On the one hand, I use a large sample of 2518 firms, in contrast with the 411 observations used by CV. This sample size allows me to obtain more accurate estimations and more precision applying hypothesis tests. On the other hand, compared with most European countries, the Spanish system of innovation is in an earlier stage of development. Compared with France, Germany and the United Kingdom, Spain presents the lowest proportion of firms with innovation expenditures and with intramural R&D. The R&D intensity (ratio of intramural R&D expenditure over total turnover) of Spanish firms performing R&D is, approximately, one third of the efforts of France, Germany and the United Kingdom. Spain also presents the lowest share of firms with R&D cooperation agreements[13]. As R&D cooperation is an important vehicle for improving the innovation performance of firms, this gap makes the study of those factors that may stimulate cooperation in R&D more interesting. Moreover, the structure of the Spanish manufacturing sector is characterized by a large share of small and low-technology firms, while the general finding in the literature is that firms from high-technology sectors and big firms are more likely to cooperate in R&D. It is worthy of exploring cooperation in such a context of small and low-technology firms.

Third, I extend CV's framework to the analysis of the determinants of R&D cooperation with competitors and I pay more attention to the relationship between cooperation and the effectiveness of different legal methods for protecting inventions or innovation.

The rest of the chapter is organized as follows. Section 1.2 introduces the data and

[13] See Abramovsky et al. (2004) for a detailed comparison in the innovation activities and performances at the national level for France, Germany, Spain and the United Kingdom.

presents some descriptive analysis of the sample. Section 1.3 introduces the framework for the analysis. The econometric specification is shown in Section 1.4. Section 1.5 presents the results. Finally, Section 1.6 concludes.

1.2. Data and descriptive analysis

The data used correspond to the Third Community Innovation Survey (CIS3; period 1998-2000), carried out in Spain by the Instituto Nacional de Estadística (INE) under the name Encuesta de Innovación Tecnológica en las Empresas. The Community Innovation Surveys take place every 4 years in European countries to investigate a firm's innovation activities. In 2001, the third wave was conducted and covered the period 1998 to 2000. The CIS3 follows the recommendations of the OSLO Manual on performing innovation surveys (see OECD and Eurostat, 1997).

Table 1.1. Characteristics of CIS3 in Spain

Responsible national authority	INE (Instituto Nacional de Estadstica)
Participation	Compulsory
Target population (number of employees)	10
Frame population	Official INE register of firms (DIRCE)
Covered sectors[1]	C, D, E, F, G, H, I, J, K, N, O
Stratification	Size, sectors
Sample	11778
Non-response analysis	no

[1]According to NACE classification: C (mining and quarrying), D (manufacturing), E (electricity, gas and water supply), F (construction), G (wholesale, retail trade, repair of motor vehicles), H (hotels), I (transport, storage and communication), J (financial intermediation), K (real estate, renting and business activities), N (health and social work), O (other community, social and personal service activities).

The Spanish CIS3 collected data on 11778 firms[14]. The population target was firms with

[14] 6094 in Manufacturing (NACE 15-37), 4778 in Services (NACE from 50 to 95), and the rest in Mining

Table 1.2. Sample Statistics

(Number and percentage of firms)

Manufacturing Firms	6026
Innovating Firms	2518 (41.8%)[1]
Non-cooperating Firms	2042 (81.1%)[2]
Cooperating Firms (at least one cooperative R&D agreement)	476 (18.9%)[2]
Firms Cooperating with Competitors	184 (7.3%)[2]
Firms Cooperating with Suppliers or Customers	316 (12.5%)[2]
Firms Cooperating with Research Institutions	425 (16.9%)[2]

[1]percentage with respect to manufacturing firms

[2]percentage with respect to innovating firms

10 or more employees. A firm is defined as the smallest combination of legal units that is an organizational unit producing goods or services. Participation is compulsory for firms and is based on stratified samples by size and sector. Unit non-response analysis is not carried out. Table 1.1 summarizes the main features of the survey for Spain.

The final sample of the manufacturing sector includes 6026 firms[15], 41.8% (2518 firms) of which report having introduced innovations during the reference period. This work restricts the attention to this subsample of innovating manufacturing firms. Innovating firms are defined as those which report having introduced product or process innovations, having ongoing innovation activities, or having abandoned innovation activities, and, at the same time, present a positive amount spent on innovation during the period 1998-2000.

Table 1.2 reports some sample statistics. It turns out that 476 firms in my sample of 2518 innovating firms (18.9%) have at least one cooperative R&D agreement. It is helpful to further distinguish among different types of cooperative R&D agreements depending on the kind of partner: 184 firms cooperate with competitors, 316 firms cooperate with suppliers or customers (vertically-related firms), and 425 firms cooperate with research institutions.

and quarrying (NACE 10-14), Electricity, gas and water supply (NACE 40-44) and Building (NACE 45).

[15]In this exercise, I drop a total of 68 manufacturing firms because of partially incomplete data.

Table 1.3. Cooperative R&D Agreement Combinations

(Number and percentage[1] of firms)

Cooperating firms with three types of agreements			159 (33.4%)
Cooperating firms with one or two types of agreements			
	Competitors	Suppliers or Customers	Research Institutions
Competitors	7 (1.5%)	9 (1.9%)	9 (1.9%)
Suppliers or Customers	–	35 (7.3%)	113 (23.8%)
Research Institutions	–	–	144 (30.2%)

[1] percentage with respect to Cooperating Firms (firms with at least one cooperative R&D agreement)

Table 1.3 shows that most firms maintain cooperative R&D agreements with different partners. Sixty-one percent of firms have agreements with at least two types of partners, and 33.4% cooperate with all three types. It is important to keep this in mind when analyzing cooperation by type of partner. For example, just 144 firms which cooperate with research institutions have agreements exclusively with these institutions, while the other 281 firms also maintain agreements with at least one other type of partner.

Table 1.4 shows the distribution of the sample of innovating manufacturing firms across industries and size. The sample presents a larger number in small firms (fewer than 200 employees) than in big firms (200 or more workers); 1748 and 770 firms, respectively. With respect to sector distribution, the sample shows a higher share of firms in low-technology sectors (63.9% of the firms belong to low-technology sectors). These facts are consistent with the Spanish manufacturing sector characteristics shown in the introduction. Focusing on R&D cooperation activity, innovative firms in high-technology manufacturing sectors and big firms are more likely to engage in cooperative activity.

Table 1.4. Number of innovating manufacturing firms by size and sector[1,2]

	Less than 200 employees	200 or more employees
Transport equipment	85 (14)	96 (38)
Chemicals	150 (49)	109 (52)
Machinery	139 (17)	46 (13)
Electrical	196 (36)	88 (39)
High-technology sectors	570 (116)	339 (142)
Food, beverages and tobacco	166 (15)	126 (33)
Textile and leather	197 (9)	45 (8)
Wood and paper	228 (10)	50 (11)
Rubber and plastic	81 (6)	37 (9)
Non-metallic mineral products	106 (11)	50 (22)
Metallic products	219 (24)	93 (39)
NEC and recycling	181 (16)	30 (5)
Low-technology sectors	1178 (91)	431 (127)
Manufacturing firms	1748 (207)	770 (269)

[1]number of innovating manufacturing firms with at least one cooperative R&D agreement between brackets

[2]Transport equipment (NACE 34-35); Chemicals (NACE 23-24); Machinery (NACE 29); Electrical (NACE 30-33); Food, beverages and tobacco (NACE 15-16); Textile and leather (NACE 17-19); Wood and paper (NACE 20-22); Rubber and plastic (NACE 25); Non-metallic mineral products (NACE 26); Metallic products (NACE 27-28); NEC and recycling (NACE 36-37)

1.3. A framework for the analysis

Based on the literature reviewed in the introduction, this chapter models the probability of cooperation as depending on spillovers, as well as the traditional variables which are thought to affect R&D cooperation (cost-risk sharing, complementarities, absorptive capacity of the firm, etc.). I include three variables related to the measure of spillovers, i.e., incoming spillovers (measured by the importance of publicly available information for the firm's innovation process), appropriability (measured by the effectiveness of the different strategic protection methods of innovations, the converse of which can be thought of as the extent of outgoing spillovers) and a measure of the importance of legal methods for protecting inventions or innovation at the industry level[16]. Detailed definitions of all employed variables can be found in Appendix 1.A.

Let me briefly comment on the expected effects of the explanatory variables.

Incoming spillovers are expected to have a positive effect on the probability of cooperation. The higher incoming spillovers are, the greater the scope for learning within cooperative R&D agreements, and hence the marginal profit to be derived from cooperation.

The sign of the effectiveness of strategic and legal protection methods (appropriability and industry level of legal protection), however, is not so clear a priori. The literature suggests two opposite effects of this variable on the probability of cooperation. The net effect will then depend on their relative importance. On the one hand, a low level of effectiveness increases the scope for the internalization of information flows between firms through cooperation in R&D. But, on the other hand, incentives to become a free rider on other firms' investments will reduce profitability and the stability of cooperative agreements.

The cost-risk variable, given the hypothesis of cost and risk sharing, is expected to show a positive effect on cooperation. To test for complementarities, a variable which measures the availability of technological know-how within the firm is included. This variable is expected

[16] As far as legal protection can be considered an industry variable rather than a firm-specific characteristic, only the average industry score for legal protection is employed. The industry is defined at the NACE 2-digit sector level.

to have a positive effect on cooperation.

Benefits from R&D cooperation depend on the absorptive capacity of the firm. In this sense, the higher the firm's absorptive capacity, the higher the returns that the firm can expect from access to external resources. On the one hand, theoretical models explicitly incorporate the need for a firm to conduct its own R&D in order to realize spillovers from other firms' R&D activity (Griffith, Redding and Van Reenen, 2003; Kaiser, 2002b; and Kamien and Zang, 2000). On the other hand, empirical studies, such as Cohen and Levinthal (1989, 1990); Griffith, Redding and Van Reenen (2003, 2004), have shown that firms' absorptive capacity depends on their own R&D intensity (R&D expenditures/turnover)[17]. So, R&D intensity is included as a measure of the absorptive capacity of the firm.

Additionally, firm's size is also included as a measure of the absorptive capacity of the firm. Therefore, I should expect a positive effect of the firm's size on the probability of cooperation. Size squared is considered to allow for a nonlinear effect of firm size.

The specification also includes the level of cooperation at the industry level, which is assumed to pick up unobserved industry-specific attributes that contribute to the decision of engaging in a cooperative R&D agreement. Table 1.5 summarizes the theoretical predictions along with the empirical findings at the end of Section 1.5.

[17] In the empirical literature, other variables have been used in order to measure the absorptive capacity of the firm. For example, Belderbos et al. (2004); and Fritsch and Lukas (2001) measure the R&D intensity by the ratio of R&D personnel to total personnel. Jaffe (1986) uses both the ratio of R&D expenditures on capital and the level of R&D expenditures. While Miotti and Sachwald (2003) and CV use a dummy variable for permanent R&D as an indicator of the absorptive capacity.

Table 1.5. Summary of hypothesis and empirical results for Spain

Variable	Hypothesis	Finding
Incoming spillovers	The importance of publicly available information has a positive effect on the probability of cooperation	True
Appropriability	The effectiveness of the strategic protection methods does not have a clear effect on the probability of cooperation	Positive effect
Industry level of legal protection	The effectiveness of the legal protection methods does not have a clear effect on the probability of cooperation	Negative effect
Cost-risk	The higher the importance of cost and risk as hampering factors for innovation, the higher the probability of cooperation	True
Complementarities	The availability of technological know-how within the firm has a positive effect on the probability of cooperation	True
R&D intensity	Benefits from R&D cooperation depend on the absorptive capacity of the firm; therefore, I expect a positive effect of R&D intensity on the probability of cooperation	True for cooperation with suppliers or customers
Size	Benefits from R&D cooperation depend on the absorptive capacity of the firm; therefore, I expect a positive effect of the firm's size on the probability of cooperation	True

1.4. Econometric specification

1.4.1. The problem of endogeneity

My concern is that some of the explanatory variables introduced in the former section are, in fact, endogenous. A priori, as in CV, I will consider the possible endogeneity of incoming spillovers, appropriability and R&D intensity. Additionally, in a departure from CV's paper, the cost-risk variable will also be taken as a possible endogenous variable. Endogeneity can arise in two different ways: omitted variables that I cannot include in the model and simultaneity in the decisions.

The propensity to cooperate in R&D can be correlated with unobserved factors that are also systematically correlated with some of the explanatory variables. First, concerning demand side factors, I can include managing capacity and quality, the choice of governance mode of R&D activities, the extent to which the firm is open to new ideas, the permeability of the firm, reputation, outward-looking style of management and tacitness of the firm's knowledge assets. For example, it is reasonable to think that the higher the manager's openness to new ideas, the higher the propensity to R&D cooperation. Additionally, the culture of openness to new ideas seems to affect, among others, the use of public sources of information (incoming spillovers) and the manager's risk aversion. Second, as for supply-side factors, I can consider the geographical proximity and the accessibility to an intensive technological area[18]. Third, of supply-demand interaction factors, I can include repeated interactions with the same partner, the length of the cooperation relationship and previous R&D cooperation agreements.

In addition to the omitted variables problem, spillovers, R&D intensity and cost-risk are also expected to be endogenous variables due to a simultaneity problem. Firstly, cooperative R&D agreements can be used to manage external knowledge flows[19], which implies that

[18] These factors can affect R&D cooperation simultaneity and variables such as R&D intensity, incoming spillovers, the effectiveness of strategic protection methods (appropriability) and the accessibility to appropriate sources of finance.

[19] See, for example, Kamien, Müller and Zang (1992).

the decision to cooperate can influence incoming spillovers as well as the effectiveness of appropriation strategies. Secondly, several studies[20] have found evidence supporting the endogeneity of R&D intensity when analyzing the R&D cooperation decision because of simultaneity in the decisions. In this sense, R&D intensity may increase if R&D cooperation makes own R&D expenditures more effective. Finally, when firms use cooperative R&D agreements to share cost and risk, the effects of cooperation can influence the importance given to these variables as obstacles to innovation.

1.4.2. System of simultaneous equations

Due to the endogeneity of a number of variables, I consider a system of simultaneous equations (see Appendix 1.B for details). The model is composed of a structural equation that is of primary interest (the cooperation equation) and a set of reduced form equations for the potential endogenous explanatory variables (incoming spillovers, appropriability, R&D intensity and cost-risk variable). The unobservable propensity to cooperate in R&D (y_1^*) is assumed to be a linear function of a set of observed exogenous explanatory variables ($\mathbf{z}_1$); such as the firm's size and the industry level of legal protection methods, a set of (possible) endogenous explanatory variables ($\mathbf{y}_2$) and an error term (u_1). Let y_1 equal 1 if the firm cooperates.

$$y_1^* = \mathbf{z}_1\boldsymbol{\delta}_1 + \mathbf{y}_2\boldsymbol{\alpha}_1 + u_1 \tag{1.1}$$

$$y_1 = 1\left[y_1^* > 0\right] \tag{1.2}$$

I assume that the endogenous explanatory variables are functions of the exogenous variables that determine cooperation ($\mathbf{z}_1$), a set of other exogenous variables ($\mathbf{z}_2$) and an error term ($\mathbf{v}_2$).

$$\mathbf{y}_2 = \mathbf{z}_1\boldsymbol{\Delta}_{21} + \mathbf{z}_2\boldsymbol{\Delta}_{22} + \mathbf{v}_2 = \mathbf{z}\boldsymbol{\Delta}_2 + \mathbf{v}_2 \tag{1.3}$$

The arguments I presented before suggest that u_1 and $\mathbf{v}_2$ are correlated. The model described by equations (1.1) – (1.3) is applicable when $\mathbf{y}_2$ is correlated with u_1 due to omitted

[20] See, among others, Becker and Dietz (2004), Colombo and Garrone (1996), and Veugelers (1997).

variables and when $\mathbf{y}_2$ is correlated with u_1 because y_2 is determined jointly with y_1 if y_1^* appears in a linear structural equation for $\mathbf{y}_2$[21].

I assume that $u_1$and $\mathbf{v}_2$ have a joint normal distribution with mean zero and finite positive covariance matrix:

$$\boldsymbol{\Omega} \equiv \begin{bmatrix} \sigma^2_{u_1} & \boldsymbol{\Sigma}_{u_1\mathbf{v}_2} \\ \boldsymbol{\Sigma}_{\mathbf{v}_2 u_1} & \boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2} \end{bmatrix} \tag{1.4}$$

Under joint normality of $(u_1, \mathbf{v}_2)$, I can write.

$$u_1 = \mathbf{v}_2\boldsymbol{\theta}_1 + e_1 \tag{1.5}$$

where $\boldsymbol{\theta}_1 = \boldsymbol{\Sigma}^{-1}_{\mathbf{v}_2\mathbf{v}_2}\boldsymbol{\Sigma}_{\mathbf{v}_2 u_1}$

1.4.3. Estimation methods

Once the endogeneity of some variables is recognized, it is clear that the estimation of the model by OLS or other techniques that do not allow for the endogeneity is inappropriate and has important consequences, i.e., in applying OLS, I will not be able to consistently estimate any of the coefficients of equation (1.1). For instance, in the empirical literature, the importance of cost and risk as obstacles to innovation has typically been considered an exogenous determinant for R&D cooperation. However, considering this variable as exogenous, it is hard to reach any broad generalization on the relation between R&D cooperation and cost-risk sharing[22]. Therefore, a proper treatment of endogeneity is necessary to obtain consistent estimates.

[21] In this case, $\mathbf{y}_2$ has the reduced form given by equation (1.3) (for a further discussion of this topic, see Maddala, 1983, Chapter 7; and Wooldridge, 2002, Chapter 15). In my case, notice that the variables used are contemporaneous, so it is plausible to think that the propensity or intention to cooperate (y_1^*), and not the actual action (y_1), should be used as an explanatory variable for $\mathbf{y}_2$.

[22] Miotti and Sachwald (2003) find that sharing costs and risks is not a significant determinant of the probability of R&D cooperation, while Tether (2002) find a positive and significant effect. Moreover, CV find a positive and significant effect of the importance of cost as a hampering factor for the innovation process of the firm, and, at the same time, the importance of risks has a negative and significant effect on R&D cooperation.

Moreover, the fact of considering an explanatory variable to be exogenous or endogenous can yield very different pictures of its importance[23].

Due to its importance, my choice is to apply a complete treatment for the endogeneity problem. Instead of, as in CV, assuming the endogeneity of some explanatory variables and using less efficient two-step procedures to obtain the final estimates, the methods applied in this study allow me, at a slight computational cost, to both test for the endogeneity of some explanatory variables of interest and obtain more efficient estimates. I use maximum likelihood estimation in order to present the final findings, while a two-step approach is used for the initial exogeneity test of some explanatory variables.

Firstly, estimating this model, I use a two-stage conditional maximum likelihood method (2SCML). This approach is due to Rivers and Vuong (1988).[24] A convenient feature of this procedure is that it provides an estimate of $\boldsymbol{\theta}_1$that can be used to test for the endogeneity of $\mathbf{y}_2$. This method is a two-step estimation procedure. In the first step, the (assumed) endogenous variables ($\mathbf{y}_2$) are regressed on all the (assumed) exogenous variables ($\mathbf{z}$). In the second step, the residuals of the first-step regressions ($\widehat{\mathbf{v}}_2$) are used as independent variables in the cooperation equation (joint with $\mathbf{z}_1$and $\mathbf{y}_2$). The usual probit t-statistic of $\widehat{\mathbf{v}}_2$ is a valid test of the null hypothesis that $\mathbf{y}_2$ is exogenous. The Rivers-Vuong approach is used for the initial test of whether $\mathbf{y}_2$ is exogenous[25].

Once the exogeneity of some explanatory variables is tested, the system of equations is estimated by conditional maximum likelihood (CML)[26]. The log likelihood function for an

[23]For example, CV considers the importance of publicly available information sources as endogenous and, using a two-step procedure, find a positive and significant effect of this variable on R&D cooperation. On the other hand, considering public incoming spillovers as exogenous, Belderbos et al. (2004) find no evidence on the effect of this variable on the probability of R&D cooperation.

[24]See Wooldridge (2002) for a recent review of this method.

[25]Note that if $\theta_1 \neq 0$, we have only estimated the coefficients up to scale.

[26]The CML estimator is a full-information maximum likelihood estimator. It is based on the entire system of equations, treats all equations and parameters jointly and gives direct estimates of the coefficients. System methods of estimation (CML) are preferred to and asymptotically better than limited information methods, or single-equation methods (2SCML), since the latter neglect information contained in other equations while the former bring efficiency gains. Moreover, the use of full information or system methods in model

individual in this model is (see Appendix B for details).

$$\log L = y_{i1} \log \mathbf{\Phi} \left(\frac{\mathbf{z}_{i1}\boldsymbol{\delta}_1 + \mathbf{y}_{i2}\boldsymbol{\alpha}_1 + (\mathbf{y}_{i2} - \mathbf{z}_i\boldsymbol{\Delta}_2)\,\boldsymbol{\theta}_1}{\left(1 - \boldsymbol{\theta}_1^{'}\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}\boldsymbol{\theta}_1\right)^{\frac{1}{2}}} \right) \tag{1.6}$$

$$+(1 - y_{i1}) \log \left[1 - \mathbf{\Phi} \left(\frac{\mathbf{z}_{i1}\boldsymbol{\delta}_1 + \mathbf{y}_{i2}\boldsymbol{\alpha}_1 + (\mathbf{y}_{i2} - \mathbf{z}_i\boldsymbol{\Delta}_2)\,\boldsymbol{\theta}_1}{\left(1 - \boldsymbol{\theta}_1^{'}\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}\boldsymbol{\theta}_1\right)^{\frac{1}{2}}} \right) \right]$$

$$-\frac{m}{2}\log(2\pi) - \frac{1}{2}\log\left|\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}\right| - \frac{1}{2}\left[(\mathbf{y}_{i2} - \mathbf{z}_i\boldsymbol{\Delta}_2)\,\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}^{-1}\,(\mathbf{y}_{i2} - \mathbf{z}_i\boldsymbol{\Delta}_2)^{'}\right]$$

1.4.4. Identification strategy and identification assumptions

The specification described above requires a set of variables ($\mathbf{z}_2$ in the notation I have been using) that are exogenous determinants of the endogenous explanatory variables but that are not determinants of the probability of cooperation. I have included in $\mathbf{z}_2$ the basicness of R&D, export intensity, industry level of incoming spillovers, industry level of appropriability, industry level of R&D intensity and industry level of cost-risk. In what follows, I define these variables, and I present the economic intuition behind these exclusion restrictions and the cases when they are included.

Kamien and Zang (2000) propose a model in which the benefit that firms obtain from incoming spillovers depends on their own R&D approach. Firms with a basic R&D approach are more likely to benefit from incoming spillovers. Following this argument, one can expect that the more basic the R&D is, the higher the score on incoming spillovers will be. The basicness of R&D is approximated by the importance of information from universities and research institutes for the innovation process. When incoming spillovers are considered an endogenous variable, basicness of R&D is included in $\mathbf{z}_2$.

The strategic protection variable can be influenced by the competitive environment of the firm. Export intensity is used as a measure of the competitive environment of the firm. The underlying premise is that competition is higher in international markets than in domestic ones, and only the most productive firms are able to make positive profits from exporting, and so there is self-selection into these markets (see Melitz, 2003). The export market is

estimation makes use of the cross-equation correlations of the disturbances.

one of substantial dynamism and exports are an important driver of firm performance (see Bernard and Jensen, 1999). So, the higher the export intensity, the higher the competition. When appropriability is considered an endogenous variable, export intensity is included in $\mathbf{z}_2$.

Also included in $\mathbf{z}_2$ as exclusion restrictions are industry-level measures (at the 2-digit NACE level) of the potentially endogenous variables[27]. These 2-digit NACE level variables are intended to capture the effect of unobserved industry-specific attributes on the corresponding potentially endogenous firm-specific variable.

The relevance and validity of these instruments are discussed in the next section.

1.5. Results

In this section, the basic model of cooperation is estimated, and the endogeneity of some explanatory variables and the relevance and validity of the instruments are tested. Once a "structure" of endogeneity is determined, the importance of different motives for participating in cooperative R&D is discussed without distinguishing the type of partner. Next, separate models for cooperation with competitors, cooperation with suppliers or customers, and cooperation with research institutions are estimated. Before this, Table 1.6 gives descriptive statistics on the main variables. As expected, most of the mean values are higher for cooperating than for non-cooperating firms.

1.5.1. Dealing with endogeneity

Table 1.7 shows the estimated coefficients of the independent variables for probit models. Standard errors are estimated for these coefficients. Regression *a* ignores endogeneity and shows the results of a one-step probit model (single-equation probit), regressions *b* to *d* show the results of 2SCML estimations, while regression *e* shows the results of CML estimation.

[27] The idea of using industry levels as instruments is conventional in microeconometric literature (see, for example, Pakes, 1983).

Table 1.6. Descriptive Statistics[1]

	Sample Mean (N=2518)	Mean non-cooperating Firms (N=2042)	Mean Cooperating Firms (N=476)	Mean Cooperation with Competitors (N=184)	Mean Cooperation with Suppliers or Customers (N=316)	Mean Cooperation with Research Institutions (N=425)
Incoming Spillovers	0.438	0.427	0.485***	0.515***	0.508***	0.490***
	(0.310)	(0.310)	(0.307)	(0.299)	(0.304)	(0.305)
Appropriability	0.214	0.186	0.335***	0.363***	0.374***	0.349***
	(0.316)	(0.298)	(0.362)	(0.366)	(0.366)	(0.363)
Industry Level Legal Protection	0.131	0.129	0.137***	0.139***	0.137***	0.137***
	(0.040)	(0.040)	(0.039)	(0.039)	(0.039)	(0.039)
Size	1.930	1.845	2.298***	2.385***	2.341***	2.329***
	(0.577)	(0.547)	(0.556)	(0.600)	(0.573)	(0.543)
Cost-Risk	0.477	0.468	0.515***	0.553***	0.538***	0.517***
	(0.317)	(0.322)	(0.291)	(0.278)	(0.282)	(0.288)
Complementarities	0.689	0.694	0.666	0.663	0.674	0.665
	(0.322)	(0.327)	(0.298)	(0.295)	(0.289)	(0.297)
R&D intensity	0.016	0.012	0.035***	0.055***	0.042***	0.036***
	(0.118)	(0.038)	(0.259)	(0.414)	(0.317)	(0.274)

***difference in means between cooperating and non-cooperating firms significant at 1%, **significant at 5%, *significant at 10%

We test the null hypothesis of equality of two means. Under the null hypothesis, the quantity $T = \frac{\sqrt{\frac{n_1 n_2}{n_1+n_2}}(\overline{X}_1 - \overline{X}_2)}{\sqrt{\sigma_1^2 \frac{n_1}{n_1+n_2-2} + \sigma_2^2 \frac{n_2}{n_1+n_2-2}}}$ has the distribution t with $n_1 + n_2$ degrees of freedom, where n_i, $\overline{X}_i$, and σ_i^2 (i=1, 2) are the number of observations from the sample of population i; the mean of the variable from the sample of population i; and the variance from the sample of population i, respectively

[1]standard deviations in parenthesis

Testing the endogeneity

Three different "structures" of endogeneity are considered a priori. Firstly, and following CV, regression b shows the 2SCML estimations considering incoming spillovers, appropriability and R&D intensity to be endogenous variables. Coefficients accompanying residuals of first-step regressions for incoming spillovers and appropriability are significant. Hence, exogeneity of these two variables is rejected. Meanwhile, the exogeneity of R&D intensity cannot be rejected.

Secondly, in regression c, I also consider cost-risk an endogenous variable. Again, I reject the exogeneity of incoming spillovers and appropriability, while the exogeneity of R&D intensity cannot be rejected. The exogeneity of cost-risk is rejected.

Finally, and due to the previous results, in regression d I consider incoming spillovers, appropriability and cost-risk to be endogenous variables. Consistent with the previous findings, the exogeneity of these three variables is rejected.

Note that, when estimating the model by the CML exogeneity of incoming spillovers, appropriability and cost-risk are also rejected (see regression e). This is the preferred "structure" of endogeneity and the one used to obtain the marginal effects.

Does the "structure" of endogeneity matter?

The "structure" of endogeneity is crucial and has important consequences for the significance and sign of the estimated coefficients.

Firstly, considering cost-risk to be an endogenous variable has an important effect on its sign. When it is "correctly" considered to be an endogenous variable, I find that it has a positive and significant effect (see regressions c, d and e), while, this variable presents a negative and significant effect when it is taken as exogenous (see regression b). Additionally, the sign of the variable complementarities seems to depend on the endogeneity of cost-risk. It has a positive and significant effect if cost-risk is "correctly" considered to be an endogenous variable (see regressions c, d and e), while it shows a negative and significant effect when the endogeneity of cost-risk is not taken into account (see regressions a and b).

Secondly, the character of R&D intensity also seems to affect the results. When it is

Table 1.7. Results of Regressions for Cooperation. Testing the Endogeneity[1]

	(*a*) Cooperation (Single-Eq. Probit)	(*b*) Cooperation (2SCML)	(*c*) Cooperation (2SCML)	(*d*) Cooperation (2SCML)	(*e*) Cooperation (CML)
Constant	-4.524^{***}	-4.621^{***}	-7.366^{***}	-7.609^{***}	-3.849^{***}
	(0.406)	(0.505)	(1.162)	(1.197)	(0.473)
Incoming Spillovers	0.217^{**}	2.662^{***}	1.822^{***}	2.124^{***}	0.717^{*}
	(0.109)	(0.518)	(0.576)	(0.504)	(0.386)
Appropriability	0.432^{***}	3.081^{***}	2.671^{***}	2.875^{***}	1.319^{***}
	(0.096)	(0.746)	(0.770)	(0.731)	(0.473)
Ind. Level Legal Protection	0.075	-4.016^{***}	-3.323^{***}	-2.977^{***}	-1.281^{**}
	(0.860)	(1.038)	(1.075)	(1.039)	(0.650)
R&D Intensity	3.136^{***}	6.558	6.407	2.039^{***}	0.873
	(0.814)	(4.343)	(4.178)	(0.720)	(0.614)
Size	1.989^{***}	1.510^{***}	1.974^{***}	1.886^{***}	0.888^{***}
	(0.326)	(0.378)	(0.412)	(0.408)	(0.284)
Size squared	-0.287^{***}	-0.219^{***}	-0.289^{***}	-0.279^{***}	-0.132^{**}
	(0.072)	(0.077)	(0.081)	(0.082)	(0.062)
Cost-Risk	0.293^{**}	-0.572^{***}	2.749^{**}	2.903^{**}	1.953^{***}
	(0.116)	(0.139)	(1.266)	(1.318)	(0.553)
Complementarities	-0.220^{**}	-0.242^{*}	1.094^{**}	1.220^{**}	0.817^{***}
	(0.111)	(0.132)	(0.521)	(0.539)	(0.224)
Ind. Level Cooperation	2.887^{***}	2.599^{***}	2.520^{***}	2.850^{***}	1.209^{***}
	(0.321)	(0.492)	(0.470)	(0.363)	(0.283)
$\theta_{\text{incoming spillovers}}$	–	-2.958^{***}	-2.117^{***}	-2.418^{***}	-0.848^{**}
		(0.535)	(0.591)	(0.522)	(0.405)
$\theta_{\text{appropriability}}$	–	-2.774^{***}	-2.358^{***}	-2.561^{***}	-1.184^{**}
		(0.751)	(0.775)	(0.736)	(0.417)
$\theta_{\text{R\&D intensity}}$	–	−4.280	−4.127	–	–
		(4.375)	(4.209)		
$\theta_{\text{cost-risk}}$	–	–	-2.578^{**}	-2.736^{**}	-1.883^{***}
			(1.269)	(1.321)	(0.564)
LL	−998.411	−895.287	−891.401	−891.867	−2217.254
χ^2	332.41^{***}	449.63^{***}	459.81^{***}	451.53^{***}	–
N	2518	2518	2518	2518	2518

***significant at 1%, **significant at 5%, *significant at 10%

[1]standard errors between brackets.

"correctly" considered to be an exogenous variable, I find that it has a positive and significant effect on the probability of cooperation (see regression *d*), while this variable loses its significance when it is considered to be endogenous (see regressions *b* and *c*).

Also, the sign and significance of the industry level of legal protection depend on considering the endogeneity problem. The single-equation probit is the only case where this variable is not significant, while the other estimates show a negative and significant effect.

Finally, and fortunately, the character of cost-risk and R&D intensity does not seem to affect the sign and significance of incoming spillovers and appropriability (compare regressions *b*, *c, d* and *e*).

Testing the relevance and validity of instruments

A plausible instrument must satisfy two conditions: relevance and validity. The relevance condition can be tested by examining the results of the first-step regressions. Table 1.A1 (see Appendix 1.C) shows the first-step regressions from which the residuals of incoming spillovers, appropriability and cost-risk for regression *d* in Table 1.7 have been obtained. As expected, each instrument is significant in the first-step regression in question. The F tests for joint significance of the exclusion restrictions in the first-step regression for incoming spillovers, appropriability and cost-risk are, respectively, 66.57, 16.40 and 13.87, which allows me to reject the null hypothesis.

In addition, Table 1.A1 shows two different R^2 as measures of the relevancy of instruments, i.e., the partial R^2 (R_p^2) and the corrected partial R^2 ($\overline{R}_p^2$)[28]. For the appropriability and the cost-risk regressions, our estimations yield larger values for $\overline{R}_p^2$ than for R_p^2. In the case of incoming spillovers regression, R_p^2 is slightly greater than $\overline{R}_p^2$. Showing these results, I can conclude that the instruments have enough relevance to explain all the endogenous regressors.[29]

In my estimation framework, testing the orthogonality condition is more problematic.

[28] The R_p^2 (see, for example Bound, Jaeger and Baker, 1995) is the R^2 of the first-step regressions with the included instruments partialled out (note that equations (1.1) and (1.3) include common exogenous variables). The $\overline{R}_p^2$, proposed by Shea (1997) takes the correlations among the instruments into account.

[29] See Baum, Schaffer and Stillman (2003) for a comparative interpretation of R_p^2 and $\overline{R}_p^2$.

The usual tests of overidentifying restrictions applied in IV or GMM estimation are not valid in a probit estimation framework. To test the orthogonality condition, a regression of the generalized residuals obtained from estimate d in Table 1.7 on the exclusion restrictions is shown in Table 1.A2 (see Appendix 1.C). Only the industry level of cost-risk is weakly significant (with an associated t-ratio equal to 1.64). This regression gives some faith in the instruments used. However, the validity of this regression for testing the orthogonality condition is not conclusive, and other tentative "experiments" have not been so optimistic[30].

I assume that it is difficult to find perfectly exogenous instruments within the CIS, where every question is closely related and, moreover, cross-section data is used. In what follows, and taking this caveat into account and having found some evidence about the orthogonality of the instruments, I will assume the validity of the instruments and the results obtained will be conditional on this assumption.

Additionally, two arguments are in my favor. Firstly, when the instruments used are not perfectly exogenous, the inconsistency of IV estimates depends on the relevance of the instruments[31]. The lower the relevance, the higher the inconsistency. And thus, the high relevance of my instruments can mitigate the inconsistency with not-perfectly exogenous instruments. Secondly, assuming the existence of invalid instruments, Hahn and Hausman (2005) find that the 2SLS has a smaller finite sample bias and MSE than the OLS under a wide range of conditions. So, in such a context of not-perfectly exogenous instruments, the 2SLS does better than the OLS in many cases[32].

[30] Considering the case of a linear probability model, the Sargan test of overidentifying restrictions rejects the joint null hypothesis of correct model specification and the validity of the overall set of instruments.

[31] See, for example, Buse (1992); Hall, Rudebusch and Wilcox (1996); Nelson and Startz (1990a, 1990b); and Staiger and Stock (1997) for the study of the consequences of low relevance of instruments in an instrumental variables estimation context.

[32] The conditions under which the 2SLS is still preferred to the OLS are derived for a linear model with one endogenous variable, and I cannot check them in my framework.

1.5.2. Determinants of cooperation

Table 1.8 shows the impact of the explanatory variables considered throughout this study on the probability of R&D cooperation. Regression *a* pays no attention to endogeneity problems, while regressions *b* and *c* estimate the model by 2SCML and CML respectively, considering incoming spillovers, appropriability and cost-risk to be endogenous variables. The preferred outcome is estimate *c*. Estimates *a* and *b* are used for checking the importance of the estimation method on the results. I find that the overall picture of the importance of the explanatory variables depends on the estimation method. In this sense, two-step procedures overestimate the importance of spillovers.

I can conclude that incoming spillovers and appropriability have a positive and significant impact on the probability of cooperation, although the impact of the effectiveness of strategic methods is almost double. In the first place, the higher incoming spillovers are, the greater the scope for learning within cooperative R&D agreements, and hence the marginal profit to be derived from cooperation. Secondly, the more effective strategic protection is, the better firms control the outflow of commercially sensitive information, and the more likely they are to engage in cooperative agreements. Fortunately, the sign and significance of these variables do not depend on the estimation method, but the magnitudes clearly vary according to the method. Above all, 2SCML and CML yield very different pictures of the impact of incoming spillovers on R&D cooperation.

It seems that the industry level of legal protection has a negative effect on R&D cooperation. A high level of legal protection methods in an industry may hamper the internalization of information flows between firms through cooperation in R&D, and hence their negative effect on this kind of practice. Taking this together with the findings on appropriability, it may be that cooperative activity is a method of internalizing outgoing knowledge flows in industries where legal protection methods are weak, and for firms for whom more strategic methods of appropriating returns are more important.

Cost-risk sharing is the most important determinant for cooperation[33]. This variable

[33] This fact is clear when estimating by CML (see regression *c*). 2SCML estimation does not yield a

Table 1.8. Results of Regressions for Cooperation. Marginal Effects[1]

	(*a*) Cooperation (Single-Eq. Probit)	(*b*) Cooperation (2SCML)	(*c*) Cooperation (CML)
Incoming Spillovers	0.049**	0.440***	0.252*
	(0.024)	(0.106)	(0.130)
Appropriability	0.097***	0.596***	0.464***
	(0.021)	(0.150)	(0.164)
Ind. Level Legal Protection	0.016	−0.617***	−0.451**
	(0.194)	(0.216)	(0.226)
R&D Intensity	0.709***	0.423***	0.307
	(0.186)	(0.150)	(0.213)
Size	0.450***	0.391***	0.312***
	(0.071)	(0.082)	(0.098)
Size squared	−0.064***	−0.057***	−0.046**
	(0.015)	(0.016)	(0.022)
Cost-Risk	0.066**	0.602**	0.687***
	(0.026)	(0.273)	(0.213)
Complementarities	−0.049**	0.253**	0.288***
	(0.025)	(0.111)	(0.086)
Ind. Level Cooperation	0.653***	0.591***	0.425***
	(0.071)	(0.109)	(0.090)
LL	−998.411	−891.867	−2217.254
χ^2	332.41***	451.53***	–
N	2518	2518	2518

***significant at 1%, **significant at 5%, *significant at 10%

[1]standard errors between brackets. The coefficients are the marginal effect of the independent variable on the probability of cooperation, ceteris paribus.

has the greatest impact on the probability of cooperation (with a marginal effect equal to 0.687). This fact possibly stresses the lack of external private finance for innovative activity and the lack of venture capital investment, which is particularly true in Spain.

The effect of firm size is positive and significant, with evidence of a concave relation. In this case, the estimated marginal effect is similar among the estimation methods.

The hypothesis that firms with a higher availability of technological know-how are more likely to cooperate is confirmed. Finally, R&D intensity seems to lose significance when estimating by CML (the associated t-ratio is 1.42).

1.5.3. Determinants of cooperation with different types of partners

As shown in Section 1.2, most firms in the sample maintain agreements with different partners. For example, it is important to take into account that when I am analyzing the subsample of firms that cooperate with research institutions, I am considering almost the whole sample of cooperating firms.

Table 1.9 presents the marginal effects for CML estimations of separate models for cooperation with different types of partners. I consider incoming spillovers, appropriability and cost-risk to be endogenous variables[34].

The effectiveness of strategic protection has a significant and positive effect on cooperation with the three types of partners. The higher the control over the information flows out of the firm (through strategic protection methods), the higher the probability of cooperation with any type of partner. Moreover, apart from the level of cooperation in the industry, appropriability is the most important determinant for cooperation with competitors. Only

clear picture about the importance of the determinants for R&D cooperation. When estimating by 2SCML, appropriability, cost-risk and industry level of cooperation have impacts around 0.6 (see regression *b*).

[34] Table 1.A3 (see Appendix 1.C) shows the tests for endogeneity. In some cases, I find only weak evidence for endogeneity of incoming spillovers and appropriability. However, for consistency, I still consider these variables endogenous. Note that, when analyzing the pooled cooperation decision, the exogeneity of R&D intensity is not rejected with an estimated coefficient accompanying residuals of the first-step regression for R&D intensity smaller than its estimated standard error (see regressions *b* and *c* in Table 1.7).

Table 1.9. Results of Regressions for Cooperation with different types of partners. Marginal Effects[1]

	(*a*) Cooperation with Competitors (CML)	(*b*) Cooperation with Suppliers or Customers (CML)	(*c*) Cooperation with Research Institutions (CML)
Incoming Spillovers	0.145	0.152	0.219^{*}
	(0.096)	(0.117)	(0.131)
Appropriability	0.247^{*}	0.445^{***}	0.485^{***}
	(0.140)	(0.150)	(0.161)
Ind. Level Legal Protection	−0.186	−0.347	-0.437^{*}
	(0.211)	(0.220)	(0.226)
R&D Intensity	0.213	0.327^{*}	0.180
	(0.200)	(0.188)	(0.177)
Size	0.163^{*}	0.239^{***}	0.331^{***}
	(0.087)	(0.092)	(0.097)
Size squared	0.017	−0.031	-0.052^{**}
	(0.018)	(0.020)	(0.021)
Cost-Risk	0.414	0.591^{**}	0.740^{***}
	(0.278)	(0.241)	(0.200)
Complementarities	0.154	0.249^{**}	0.315^{***}
	(0.116)	(0.099)	(0.081)
Ind. Level of Cooperation with Competitors	0.587^{***}	–	–
	(0.120)		
Ind. Level of Cooperation with Suppliers or Customers	–	0.438^{***}	–
		(0.111)	
Ind. Level of Cooperation with Research Institutions	–	–	0.398^{***}
			(0.099)
LL	−1848.246	−2062.711	−2114.616
N	2518	2518	2518

***significant at 1%, **significant at 5%, *significant at 10%

[1]standard errors between brackets. The coefficients are the marginal effect of the independent variable on the probability of cooperation, ceteris paribus.

those firms with very effective strategic protection methods will share “knowledge” with their competitors.

Coinciding with CV’s findings, incoming spillovers seem to have an effect only on cooperation with research institutions. Firms which find publicly available information more important for their innovation process are more likely to benefit from cooperation with research institutions.

The effectiveness of the industry level of legal protection methods has a significant and negative effect only on cooperation with research institutions. It seems that a high level of these types of protection methods hampers the internalization of information flows between firms and research institutions more than with the other types of partners.

For cooperation with suppliers and customers and cooperation with research institutions, cost-risk sharing is the most important determinant for cooperation. Also, availability of technological know-how has a positive and significant effect on cooperation.

For cooperation with suppliers or customers, I find a positive and (weak) significant effect of R&D intensity. This variable loses significance for cooperation with competitors and cooperation with research institutions. For the three types of cooperative agreements, firm size is an important determinant for R&D cooperation.

The empirical results are summarized and compare to the hypothesis in Table 1.5.

1.6. Conclusions

This chapter is aimed at exploring the determinants of R&D cooperation using a sample of Spanish manufacturing firms. A first step focuses on studying the endogeneity of the explanatory variables which in other papers are assumed to be endogenous a priori. I find evidence supporting endogeneity of spillovers and the importance of cost-risk as a hampering factor for the innovation process. The choice of an appropriate “structure” of endogeneity is revealed to be crucial in the significance and sign of some of the estimated effects. In this sense, cost-risk sharing and complementarities have only the expected positive effect on R&D cooperation when the appropriate “structure” of endogeneity is imposed, while if this “structure” is not imposed, these variables have a negative effect.

I also find that the overall picture of the importance of the explanatory variables on the probability of R&D cooperation depends on the estimation technique. Specifically, two-step procedures overestimate the importance of spillovers and underestimate the impact of cost and risk-sharing reasons. So, in obtaining the final estimated effects, I apply a more efficient method, i.e., CML estimation.

Evidence supporting the existence of important and separately identifiable effects of incoming spillovers and appropriability on R&D cooperation is obtained: the higher incoming spillovers are and the more effective the strategic appropriation methods of the returns from innovation is, the higher the probability of R&D cooperation. However, and in a departure from other empirical works, the level of legal protection in the industry has a negative effect on R&D cooperation.

In spite of the importance of spillovers, I find that cost-risk sharing is the most important determinant for R&D cooperation. This fact possibly stresses the lack of external private finance for innovative activity and the lack of venture capital investment, which is particularly true in Spain.

Results also show that firm size and the availability of technological know-how within the firm are significant and positive determinants of R&D cooperation.

The results are not so clear when analyzing cooperation with each different type of partner. Most firms have simultaneous agreements with different types of partners and this makes identification difficult. However, two principal ideas can be advanced. First of all, for cooperation with suppliers and customers and cooperation with research institutions, cost-risk sharing is the most important determinant for cooperation. Secondly, effectiveness of strategic protection methods is the most important determinant for cooperation with competitors.

Appendix 1.A. Variable definitions

Appropriability: Sum of the scores of the following strategic methods for protecting inventions or innovations (number between 1 (high) and 4 (not used)): Secrecy; Complexity of design; Lead-time advantage on competitors. Rescaled between 0 (not used) and 1 (high).

Basicness of R&D: Sum of the scores of importance of the following information sources for innovation process (number between 1 (high) and 4 (not used)): Universities; government or private non-profit research institutes. Rescaled between 0 (not used) and 1 (high).

Complementarities: Importance of lack of information on technology as an obstacle to innovation (number between 1 (high) and 4 (not relevant). Rescaled between 0 (high) and 1 (not-relevant).

Cooperation: Variable which takes the value 1 if the firm cooperates with suppliers, customers, competitors, commercial laboratories/R&D enterprises, universities, or government or private non-profit research institutes.

Cooperation with Competitors: Variable which takes the value 1 if the firm cooperates with competitors.

Cooperation with Research Institutions: Variable which takes the value 1 if the firm cooperates with commercial laboratories/R&D enterprises, universities, or government or private non-profit research institutes.

Cooperation with Suppliers or Customers: Variable which takes the value 1 if the firm cooperates with suppliers or customers.

Cost-Risk: Sum of the scores of importance of the following obstacles to innovation process (number between 1 (high) and 4 (not relevant)): Innovation costs too high; Lack of appropriate sources of finance; Excessive perceived economic risks. Rescaled between 0 (not relevant) and 1 (high).

Export intensity: Export share in total turnover.

Incoming Spillovers: Sum of the scores of importance of the following information sources for innovation process (number between 1 (high) and 4 (not used)): Professional conferences, meetings and journals; Fairs and exhibitions. Rescaled between 0 (not used) and 1 (high).

Industry Level of Appropriability: Mean of Appropriability at the industry level. Industry is defined at 2-digit NACE.

Industry Level of Cooperation: Mean of Cooperation at the industry level. Industry is defined at 2-digit NACE.

Industry Level of Cooperation with Competitors: Mean of Cooperation with competitors at the industry level. Industry is defined at 2-digit NACE.

Industry Level of Cooperation with Research Institutions: Mean of Cooperation with research institutions at the industry level. Industry is defined at 2-digit NACE.

Industry Level of Cooperation with Suppliers or Customers: Mean of Cooperation with suppliers or customers at the industry level. Industry is defined at 2-digit NACE.

Industry Level of Cost-Risk: Mean of Cost-risk at the industry level. Industry is defined at 2-digit NACE.

Industry Level of Incoming Spillovers: Mean of Incoming Spillovers at the industry level. Industry is defined at 2-digit NACE.

Industry Level of Legal Protection: Mean of Legal Protection at the industry level. Legal Protection is the sum of the scores of the following legal methods for protecting inventions or innovations (number between 1 (high) and 4 (not-used)): Patents; Registration of design patterns; Trademarks; Copyright. Rescaled between 0 (not-used) and 1 (high). Industry is defined at 2-digit NACE.

Industry Level of R&D intensity: Mean of R&D intensity at the industry level. Industry is defined at 2-digit NACE.

R&D intensity: Ratio between intramural R&D expenditure and turnover.

Size: Log of number of employees.

Appendix 1.B. Econometric details

Let y_1^* represent a firm's unobservable propensity to cooperate in R&D. y_1^* is assumed to be a linear function of the previously observed explanatory variables. Let y_1 equal 1 if the firm cooperates.

I assume that the (possible) endogenous explanatory variables ($\mathbf{y}_2$) are a function of the exogenous variables that determine cooperation ($\mathbf{z}_1$), a set of other exogenous variables ($\mathbf{z}_2$), and an error term ($\mathbf{v}_2$).

So, the model can be written as follows:

$$y_1^* = \mathbf{z}_1\boldsymbol{\delta}_1 + \mathbf{y}_2\boldsymbol{\alpha}_1 + u_1 \tag{1.a.}$$

$$\mathbf{y}_2 = \mathbf{z}_1\boldsymbol{\Delta}_{21} + \mathbf{z}_2\boldsymbol{\Delta}_{22} + \mathbf{v}_2 = \mathbf{z}\boldsymbol{\Delta}_2 + \mathbf{v}_2 \tag{2.a.}$$

$$y_1 = 1\left[y_1^* > 0\right] \tag{3.a.}$$

Where $\mathbf{z}_1, \mathbf{y}_2, \mathbf{z}_2$ and $\mathbf{z}$ are $1 \times p, 1 \times m, 1 \times k$ and $1 \times (p + k)$ vectors, respectively. Note that $\boldsymbol{\Delta}_{21}, \boldsymbol{\Delta}_{22}$ and $\boldsymbol{\Delta}_2$ are $p \times m, k \times m$ and $(p + k) \times m$ matrices, respectively.

$u_1$and $\mathbf{v}_2$ have a joint normal distribution with mean zero and finite positive covariance matrix:

$$\boldsymbol{\Omega} \equiv \begin{bmatrix} \sigma_{u_1}^2 & \boldsymbol{\Sigma}_{u_1\mathbf{v}_2} \\ \boldsymbol{\Sigma}_{\mathbf{v}_2 u_1} & \boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2} \end{bmatrix}$$

The most convenient normalization is:

$$\sigma_{u_1}^2 = Var(u_1) = 1$$

This is the normalization imposed by Wooldridge (2002), and is different from that used by Rivers and Vuong (1988), who use the normalization

$$Var(y_1^* \mid z, y_2) = \sigma_{u_1}^2 - \boldsymbol{\theta}_1^{\prime}\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}\boldsymbol{\theta}_1 = 1$$

Under joint normality of $(u_1, \mathbf{v}_2)$, I can write

$$u_1 = \mathbf{v}_2\boldsymbol{\theta}_1 + e_1 \tag{4.a.}$$

where $\boldsymbol{\theta}_1 = \boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}^{-1}\boldsymbol{\Sigma}_{\mathbf{v}_2 u_1}$. To obtain the joint distribution of $(y_1,\mathbf{y}_2)$, conditional on $\mathbf{z}$, recall that

$$f\left(y_1,\mathbf{y}_2 \mid \mathbf{z}\right) = f\left(y_1 \mid \mathbf{y}_2, \mathbf{z}\right) f\left(\mathbf{y}_2 \mid \mathbf{z}\right) \tag{5.a.}$$

Since $\mathbf{v}_2$ has a joint normal distribution with mean zero and covariance matrix $\Sigma_{\mathbf{v}_2\mathbf{v}_2}$, the joint density $f\left(\mathbf{y}_2 \mid \mathbf{z}\right)$ is easy to write down:

$$f\left(\mathbf{y}_2 \mid \mathbf{z}\right) = (2\pi)^{-\frac{m}{2}} \left|\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}\right|^{-\frac{1}{2}} \exp\left\{-\frac{1}{2}\left(\mathbf{y}_2 - \mathbf{z}\boldsymbol{\Delta}_2\right)\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}^{-1}\left(\mathbf{y}_2 - \mathbf{z}\boldsymbol{\Delta}_2\right)^{'}\right\} \tag{6.a.}$$

I can also derive the conditional density of y_1 given $(\mathbf{y}_2, \mathbf{z})$. Because of joint normality of $(u_1, \mathbf{v}_2)$, e_1 is also normally distributed with $E(e_1) = 0$ and $Var(e_1) = Var(u_1) - \boldsymbol{\theta}_1^{'}\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}\boldsymbol{\theta}_1 = 1 - \boldsymbol{\theta}_1^{'}\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}\boldsymbol{\theta}_1$

Since $(1.a.)$ and $(4.a.)$, I can write

$$y_1^* = \mathbf{z}_1\boldsymbol{\delta}_1 + \mathbf{y}_2\boldsymbol{\alpha}_1 + \mathbf{v}_2\boldsymbol{\theta}_1 + e_1 \tag{7.a.}$$

$$e_1 \mid \mathbf{z}, \mathbf{y}_2, \mathbf{v}_2 \sim N\left(0, 1 - \boldsymbol{\theta}_1^{'}\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}\boldsymbol{\theta}_1\right) \tag{8.a.}$$

Since $\mathbf{v}_2 = \mathbf{y}_2 - \mathbf{z}\ \boldsymbol{\Delta}_2$ and $y_1 = 1\left[y_1^* > 0\right]$

$$P(y_1 = 1 \mid \mathbf{y}_2, \mathbf{z}) = \boldsymbol{\Phi}\left(\frac{\mathbf{z}_1\boldsymbol{\delta}_1 + \mathbf{y}_2\boldsymbol{\alpha}_1 + \left(\mathbf{y}_2 - \mathbf{z}\boldsymbol{\Delta}_2\right)\boldsymbol{\theta}_1}{\left(1 - \boldsymbol{\theta}_1^{'}\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}\boldsymbol{\theta}_1\right)^{\frac{1}{2}}}\right) \tag{9.a.}$$

Let w denote the term inside $\boldsymbol{\Phi}(\cdot)$ in equation $(9.a.)$. Then I derive

$$f\left(y_1 \mid \mathbf{y}_2, \mathbf{z}\right) = \left\{\boldsymbol{\Phi}(\cdot)\right\}^{y_1}\left\{1 - \boldsymbol{\Phi}(\cdot)\right\}^{1-y_1} \tag{10.a.}$$

Substituting $(6.a.)$ and $(10.a.)$ in $(5.a.)$, I can write

$$\begin{aligned} f\left(y_1,\mathbf{y}_2 \mid \mathbf{z}\right) \;=\; & \left\{\boldsymbol{\Phi}(\cdot)\right\}^{y_1}\left\{1 - \boldsymbol{\Phi}(\cdot)\right\}^{1-y_1}(2\pi)^{-\frac{m}{2}}\left|\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}\right|^{-\frac{1}{2}} \\ & \exp\left\{-\frac{1}{2}\left(\mathbf{y}_2 - \mathbf{z}\boldsymbol{\Delta}_2\right)\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}^{-1}\left(\mathbf{y}_2 - \mathbf{z}\boldsymbol{\Delta}_2\right)^{'}\right\} \end{aligned} \tag{11.a.}$$

and so the log likelihood for observation i is

$$\begin{aligned} & y_{i1}\log\boldsymbol{\Phi}\left(w_i\right) + \left(1 - y_{i1}\right)\log\left[1 - \boldsymbol{\Phi}\left(w_i\right)\right] \\ & -\frac{m}{2}\log(2\pi) - \frac{1}{2}\log\left|\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}\right| - \frac{1}{2}\left[\left(\mathbf{y}_{i2} - \mathbf{z}_i\boldsymbol{\Delta}_2\right)\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}^{-1}\left(\mathbf{y}_{i2} - \mathbf{z}_i\boldsymbol{\Delta}_2\right)^{'}\right] \end{aligned} \tag{12.a.}$$

where I understand that w_i depends on the parameters $(\boldsymbol{\delta}_1, \boldsymbol{\alpha}_1, \boldsymbol{\Delta}_2, \boldsymbol{\theta}_1)$:

$$w_i \equiv \frac{\mathbf{z}_{i1}\boldsymbol{\delta}_1 + \mathbf{y}_{i2}\boldsymbol{\alpha}_1 + (\mathbf{y}_{i2} - \mathbf{z}_i\boldsymbol{\Delta}_2)\,\boldsymbol{\theta}_1}{\left(1 - \boldsymbol{\theta}_1^{\prime}\boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}\boldsymbol{\theta}_1\right)^{\frac{1}{2}}}$$

Summing expression (12.a.) across all i and maximizing with respect to all parameters gives the MLEs of $\boldsymbol{\delta}_1, \boldsymbol{\alpha}_1, \boldsymbol{\Delta}_2, \boldsymbol{\Sigma}_{\mathbf{v}_2\mathbf{v}_2}, \boldsymbol{\theta}_1$. The estimate of $\boldsymbol{\theta}_1$ can be used to test for endogeneity of $\mathbf{y}_2$.

Notice that, if u_1 and v_2 are uncorrelated and thus $\theta_1 = 0$, the log likelihood function in equation (12.a.) can be broken into two terms. The first line would be the log likelihood function for a single equation probit associated with y_1, and the second line would be the log likelihood function for the normal linear least-squares model associated with y_2. Thus, if $\theta_1 = 0$, there is no gain in considering the simultaneous equation model. If $\theta_1 \neq 0$, however, the single-equation model and the simultaneous equation model can yield very different coefficient estimates.

Appendix 1.C. Additional tables

Table 1.A1. Results of first-step regressions used for constructing the reduced form residuals of Incoming Spillovers, Appropriability and Cost-Risk of Table 1.7, regression (*d*)[1]

	(a) Incoming Spillovers	(b) Appropriability	(c) Cost-Risk
Size	−0.070	0.082	−0.120**
	(0.056)	(0.061)	(0.057)
Size squared	0.008	−0.009	0.015
	(0.012)	(0.015)	(0.013)
Ind. Level Legal Protection	0.044	0.068	−0.087
	(0.226)	(0.247)	(0.217)
R&D Intensity	0.001	0.047	0.072**
	(0.021)	(0.082)	(0.033)
Complementarities	−0.053***	−0.041**	−0.414***
	(0.018)	(0.018)	(0.018)
Basicness of R&D	0.371***	0.171***	0.135***
	(0.023)	(0.027)	(0.021)
Export intensity	−0.016	0.126***	−0.006
	(0.023)	(0.027)	(0.022)
Ind. Level of Cooperation	−0.104	−0.102	0.032
	(0.077)	(0.078)	(0.078)
Ind. Level of Incoming Spillovers	0.901***	0.077	0.003
	(0.126)	(0.128)	(0.129)
Ind. Level of Appropriability	−0.073	0.768***	0.084
	(0.198)	(0.214)	(0.195)
Ind. Level of Cost-Risk	0.030	0.071	0.850***
	(0.179)	(0.193)	(0.167)
Constant	0.124	−0.163	0.484***
	(0.123)	(0.130)	(0.116)
R_p^2	0.104	0.037	0.018
$\overline{R}_p^2$	0.081	0.061	0.180
F(11, 2506)	34.90	20.41	66.96
F(5, 2506)[2]	66.57	16.40	13.87
N	2518	2518	2518

***significant at 1%, **significant at 5%, *significant at 10%

[1]Estimation method: OLS. Robust standard errors between brackets.

[2]F test for joint significance of the exclusion restrictions: basicness of R&D, export intensity, industry level of incoming spillovers, industry level of appropriability and industry level of cost-risk.

Table 1.A2. Results of the regression of the generalized residuals of estimate d in Table 1.7 on the exclusion restrictions[1]

	Generalized Residuals
Basicness of R&D	0.037
	(0.028)
Export intensity	0.025
	(0.029)
Ind. Level of Incoming Spillovers	−0.169
	(0.122)
Ind. Level of Appropriability	−0.129
	(0.125)
Ind. Level of Cost-Risk	0.183*
	(0.111)
R^2	0.002
F(5, 2513)	1.35
N	2518

***significant at 1%, **significant at 5%, *significant at 10%

[1]Estimation method: OLS. Robust standard errors between brackets.

Table 1.A3. Results of Regressions for Cooperation with different types of partners. Testing the Endogeneity[1]

	(*a*) Cooperation with Competitors (CML)	(*b*) Cooperation with Suppliers or Customers (CML)	(*c*) Cooperation with Research Institutions (CML)
Constant	-4.161^{***}	-3.932^{***}	-3.958^{***}
	(0.645)	(0.560)	(0.464)
Incoming Spillovers	0.648	0.502	0.624^{*}
	(0.529)	(0.418)	(0.389)
Appropriability	1.105^{*}	1.467^{***}	1.381^{***}
	(0.661)	(0.517)	(0.469)
Ind. Level Legal Protection	-0.832	-1.146	-1.243^{*}
	(0.971)	(0.746)	(0.649)
R&D Intensity	0.953	1.078^{*}	0.513
	(0.957)	(0.654)	(0.509)
Size	0.730^{**}	0.789^{***}	0.943^{***}
	(0.364)	(0.307)	(0.286)
Size squared	-0.075	-0.102	-0.147^{**}
	(0.077)	(0.065)	(0.062)
Cost-Risk	1.852^{**}	1.950^{***}	2.107^{***}
	(0.886)	(0.662)	(0.510)
Complementarities	0.690^{*}	0.821^{***}	0.897^{***}
	(0.384)	(0.270)	(0.204)
Ind. Level of Cooperation with Competitors	2.630^{***}	–	–
	(0.690)		
Ind. Level of Cooperation with Suppliers or Customers	–	1.447^{***}	–
		(0.434)	
Ind. Level of Cooperation with Research Institutions	–	–	1.132^{***}
			(0.307)
$\theta_{\text{incoming spillovers}}$	-0.716	-0.541	-0.767^{*}
	(0.540)	(0.428)	(0.411)
$\theta_{\text{appropriability}}$	-0.936	-1.242^{**}	-1.240^{***}
	(0.656)	(0.512)	(0.466)
$\theta_{\text{cost-risk}}$	-1.597^{*}	-1.759^{**}	-2.049^{***}
	(0.938)	(0.686)	(0.519)
LL	-1848.246	-2062.711	-2114.616
N	2518	2518	2518

***significant at 1%, **significant at 5%, *significant at 10%

[1]standard errors between brackets.

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CHAPTER 2. UNDERSTANDING COOPERATIVE INNOVATIVE ACTIVITY: EVIDENCE FROM FOUR EUROPEAN COUNTRIES

2.1. Introduction

This chapter investigates the extent to which European firms engage in cooperative innovation, and aims to shed light on the determinants of such activity. Cooperative innovative activity is a topical policy issue, in the context of technology transfer (most prominently from universities to business) and in its interactions with competition policy. Both the OECD and the European Union support the idea of strong industry-science linkages to maximise the returns from both private and public research investments, and recognise a role for policy intervention[35].

In 2003, the UK government conducted a major review of the extent of business-university collaboration, which suggested ways to improve government support for such activity[36]. The UK currently operates a number of schemes aimed at encouraging collaborative innovative activity between businesses and research institutions, and business-to-business linkages. In Germany a significant amount of public funding for innovative activity is now directed towards research consortia comprising private businesses and scientific research institutions, and policies in France and Spain also emphasise public-private sector collaboration[37]. In this context it is important to understand which types of firms tend to engage in cooperative innovative activities, the motivations for such activity and whether public policy is effective in increasing collaborative research.

In this study I focus (similar to Chapter 1) on the roles of knowledge flows, cost- and risk-sharing and public financial support in influencing firms' decisions to enter into coop-

[35] OECD (2004a,b), European Commission (2004a).

[36] HM Treasury (2003).

[37] See Abramovsky et al. (2004a) for a summary for the UK, Fier et al. (2006) for information on the direction of funding in Germany, Acosta and Modrego (2001) for further information for Spain, and MNRT (2005) for further information for France.

erative innovation agreements. To do this, I build on the framework developed in Cassiman and Veugelers (2002) (henceforth CV) that looks at the effects of information flows, both incoming and outgoing knowledge spillovers, on the likelihood of engaging in cooperative innovative activity, using data from the 1st Community Innovation Survey (CIS) for Belgian manufacturing firms.

I contribute to the literature by extending the analysis in CV in a number of ways. First, I provide a comparison of the characteristics of firms engaging in cooperative innovation activities across four major European countries (France, Germany, Spain and the UK), using internationally comparable firm-level data from the 3rd Community Innovation Survey (CIS3). Second, I include the service sector in the analysis, which is rarely considered in empirical studies. Using the CIS is particularly appealing for this purpose as it focuses on a wide concept of innovation activities likely to be more applicable to the service sector compared to the narrower definition of R&D expenditure. Finally, I extend the analysis in CV by considering cooperative innovation with competitors in addition to with the research base and with firms' suppliers and customers, and also consider the relationship between receipt of public financial support for innovation and the likelihood of collaboration.

I find that firms which place a higher value on external information flows, or incoming knowledge spillovers, are more likely to engage in cooperative innovative arrangements. Moreover, incoming spillovers are found to play a more important role in collaborative arrangements with research institutions than with other firms, which is consistent with the evidence presented in CV. I find that firms which potentially face difficulties in appropriating the returns to their innovative efforts, and which are reliant on strategic protection methods such as secrecy to limit outgoing knowledge spillovers, are more likely to engage in collaborative innovation with the research base and with upstream and downstream firms than with firms with which they are in direct competition. This is consistent with free-riding being a more serious problem within agreements between rivals.

I also find some evidence, in particular for firms in Spain, that cooperative innovative arrangements are motivated by a need to overcome financial constraints, potentially reflecting differences in capital markets across countries. Finally, as might be expected given the orientation of public support for innovation towards university-business technology transfer, I find a positive relationship between receipt of financial public support for innovative activities and the probability of cooperating with the research base, and to a lesser extent with the probability of cooperating with other firms. The relationship between receipt of public support and cooperation is the weakest with respect to collaboration with competitors, where competition policy concerns might be the most likely to come into play.

The chapter is structured as follows. The next section discusses reasons why firms might engage in collaborative innovative activity, including the relationship with both incoming and outgoing information flows. Section 2.3 describes the data, presents some cross-country descriptive statistics on the degree to which innovative firms engage in cooperative innovation, and defines the variables used in estimation. Section 2.4 presents empirical results on the firm characteristics associated with cooperative activity, looking separately at cooperation with different partners, in each country. I attempt to deal with potential endogeneity concerns using instrumental variable methods. Section 2.5 concludes.

2.2. Why do firms undertake collaborative innovative activity?

Firms may engage in collaborative innovative activity for a variety of reasons[38]. In this study I focus on the roles of inward and outward knowledge flows, cooperation as a means of overcoming constraints and the direction of public policy schemes. I discuss each of these factors in turn and consider how their influence might vary with the characteristics of the collaborative partner[39].

The analysis of knowledge spillovers and R&D cooperation has a long tradition in the theoretical literature[40]. Economic theory argues that R&D cooperation can help to internalise knowledge spillovers arising from inventive activity and as a result increase social welfare.

[38] See, inter alia, Hagedoorn (1993), Glaister and Buckley (1996), Narula and Hagedoorn (1999), Cassiman and Veugelers (2002), and Miotti and Sachwald (2003).

[39] This discussion is closely related to that presented in Chapter 1.

[40] See, inter alia, Kamien et al. (1992), D'Aspremont and Jacquemin (1988), Katz (1986), and Katsoulacos and Ulph (1998).

Recent empirical literature has been inspired by these findings and has increasingly paid attention to the relationship between R&D cooperation and knowledge spillovers[41]. Almost all empirical studies confirm that generating or preventing a range of knowledge flows is a motive for firms to cooperate. The analysis in CV has been particularly influential. They focus on the influence of two types of knowledge flows on the likelihood of cooperation, first the extent of incoming spillovers, that is beneficial knowledge flows from external sources; and second appropriability, that is firms' ability to capture the returns to their innovative activity, the converse of which can be thought of as the extent of outgoing spillovers. CV find that these two types of knowledge spillovers have important and separately identifiable effects on the probability that firms engage in cooperative R&D.

Firms that place a higher value on incoming spillovers and externally generated knowledge in their innovative activity might exhibit greater scope for learning, and be more likely to gain from knowledge exchange within a cooperative agreement. Hence they would be expected to be more likely to undertake collaborative innovative activity. CV confirm the existence of a positive relationship between the magnitude of incoming knowledge spillovers and the probability of cooperation, in particular when analysing collaboration with research institutions. It might be expected that firms which are able to capitalise on a diverse set of external knowledge might be more likely to engage in collaborative ventures with the research base or with firms outside their own industry. The extent to which different motives for collaboration vary with different partners, especially the relationship between firms and universities, has recently gained increasing importance in the literature[42] and in public policy formation[43].

The degree to which firms value incoming spillovers will depend on their absorptive capacity, hence it is important to control for this factor in an empirical analysis. Cohen and Levinthal (1989, p.569) define absorptive capacity as a "firm's ability to identify, assimilate, and exploit knowledge from the environment." Absorptive capacity will influence the extent

[41] See, for example, Belderbos et al. (2004) for evidence for the Netherlands, Kaiser (2002) for evidence for the German service sector, and Cassiman and Veugelers (2002) for Belgium.

[42] See, inter alia, Belderbos et al. (2004), Bönte and Keilbach (2005), and Cassiman and Veugelers (2002).

[43] See, for example, HM Treasury (2003).

to which firms can use external knowledge flows either to imitate or to innovate, depending on a firm's position relative to the technological frontier. Firms with higher absorptive capacity might be more likely to be successful innovators, which could make them more attractive cooperation partners for other firms. However, how a firm's absorptive capacity affects its own incentives to engage in cooperative R&D is ambiguous. On the one hand, firms that are better at accessing and using external knowledge can more easily benefit from the knowledge available to them for free and might thus have lower incentives to cooperate. On the other hand, if they are also better able to profit from the knowledge exchanged within a cooperative agreement, their incentives to cooperate could be higher[44]. Evidence on the importance of absorptive capacity in determining firms' decisions to cooperate on innovation activities is found, for example, in Sakakibara (1997), Tether (2002) and Bayona et al. (2001). In my analysis below I control for absorptive capacity using a measure of R&D intensity, (which may capture R&D aimed at imitative or at innovative activity), along with a measure of firm size.

The influence of appropriability problems on firms' incentives to engage in collaborative innovative activity is ex-ante ambiguous, and might be expected to vary with the type of collaborative partner. On one hand, in the face of appropriability problems firms might try and internalise outgoing spillovers by forming explicit collaborative relationships, rather than conducting innovation activities on their own. On the other, an inability to appropriate the returns to one's own innovative efforts, even inside a collaborative arrangement, might lead to free-riding either inside[45] or outside[46] collaborative agreements and hence decrease the likelihood of such agreements occurring, by reducing the incentives for firms to form them.

[44] Hagedoorn (1993) argues that access to complementary knowledge and technologies is one of the most important motives for firms to engage in cooperative research. The resource based view supports this (see, for instance, Mowery et al. (1998)).

[45] Kesteloot and Veugelers (1995), for example, found that the incentive to cheat within a cooperative agreement increases if outgoing spillovers are high, thus decreasing the incentive to cooperate in the first place.

[46] See Greenlee and Cassiman (1999).

I might expect incentives to free-ride to be most prevalent within collaborative arrangements with competitor firms, where appropriability problems might be most severe. Hence firms facing appropriability problems might be less likely to engage in this type of agreement compared to agreements with more dissimilar partners where free-riding may be less feasible, and the incentives to do so much lower since they are not competing face-toface in the same market. Appropriability problems, by causing cooperation to break down, may lead to collaborative agreements between rival firms being less prevalent. Veugelers and Kesteloot (1994) provide an analysis of the design of stable research joint ventures, emphasising conditions under which incentives to cheat are reduced. They highlight the role of complementary capabilities between partner firms and the degree to which firms can keep their own knowledge proprietary within an agreement as important factors in generating stable agreements.

Other important motives for cooperative innovative activity identified in the literature are sharing both the costs and risks associated with an R&D project, leading to higher expected profits than if the projects were carried out individually. This argument is supported, for example, by the evidence provided in Belderbos et al. (2004), Hagedoorn (1993), Miotti and Sachwald (2003), Sakakibara (1997), Tether (2002) and Tyler and Steensma (1995). Basic research projects tend to be riskier than applied, more commercially oriented projects. Hence, I might expect cost and risk sharing motivations to be more important for cooperation agreements with the research base if the innovative activity undertaken is more orientated towards basic research compared to that carried-out within agreements with other firms.

While firms may undertake collaborative innovative activities to overcome financial constraints or to pool risks, they may nonetheless face other constraints to cooperative activity, for example, the presence of market failures, such as co-ordination or information failures. These may rationalise the existence of public support programmes to encourage cooperative R&D and technology transfer between universities and firms, and firms and firms alike. Supporting cooperation and knowledge sharing among actors in the national, regional or local innovation system may increase social welfare and enhance the innovative capacity of firms. In order to achieve a high level of knowledge sharing among actors, public funding for R&D and innovation activities is increasingly linked to cooperative innovation activities, and aims to facilitate cooperative innovation by firms that would otherwise not engage in such activity.

As discussed in more detail in Section 2.4, this public funding is primarily targeted at university-firm collaboration, where institutional incentives for university scientists to engage in technology transfer to firms might otherwise be weak. I therefore expect to find the strongest relationship between receipt of public support and cooperation with the research base[47]. Moreover I might expect to find a much weaker relationship with respect to cooperation with competitors. Public support is less likely to be directed at this form of collaboration since it may raise policy concerns of a quite different nature, in terms of restrictions on the degree of product market competition ex-post.

Indeed anti-trust concerns might be a further reason why I might expect to observe fewer agreements between competing firms. Much of the literature on R&D cooperation has focussed on models of rival firms. Katz and Ordover (1990) provide a discussion of policy towards collaborative research in the context of potential effects on competition. Their analysis emphasises that the welfare effects of ex-ante cooperation hinge on the environment in which R&D cooperation and product market competition take place, for example the extent of technological spillovers and whether the firms' products are market substitutes or complements. Related to this, D'Aspremont and Jacquemin (1988) analyse effects dependent on the degree of knowledge spillovers, and Kamien et al. (1992) carry out a welfare analysis of different types of R&D competition and cooperation, incorporating different models of product market rivalry. As discussed above incentives to free-ride might also be strongest within agreements between rivals, and problems due to incomplete contracts (the difficulties of contracting on, observing and verifying all relevant potential actions within an

[47] While I would expect to find a positive correlation between cooperative R&D activity and receipt of public support, this does not necessarily imply that policies are generating additional cooperative research. It maybe that some of those firms receiving support would have engaged in some form of cooperative innovative activity in any case.

R&D partnership) might also lead to agreements between competitors being less frequent in practice.

The discussion above highlights that the extent to which firms benefit from incoming spillovers, the extent to which they can appropriate the returns to their innovative activity, and whether or not they face constraints in their innovation activities may themselves depend on whether or not firms engage in cooperative innovation, in addition to other firm and industry-specific factors. Following CV, my empirical framework, outlined in Section 2.4.1, attempts to take account for this potential endogeneity. Before turning to results, I next present some descriptive statistics on the propensity of innovative firms to undertake cooperative innovative activity, and on the characteristics of firms that do so.

2.3. Data and descriptive statistics

As in the previous chapter, the source of the data is the 3rd Community Innovation Survey (CIS3, carried out in 2001). At this point I focus on a comparison of the characteristics of CIS3 across France, Germany, Spain and the UK. Table 1.2 summarizes the main features of the survey in each of the four countries considered. The questionnaire - including definitions - which was sent by post to the firms is harmonised across countries and includes some core as well as some optional questions. Beyond the questionnaires, statistical survey methods, as well as data mining and analytical methods are co-ordinated by Eurostat.

CIS3 covers all enterprises with 10 or more employees. In France however, the target population covers firms with 20 or more employees, hence for comparability I restrict the analysis to firms with more than 20 employees in each country. Appendix 2.A provides a list of the manufacturing and services industries included in my analysis[48].

[48] A more detailed description of the survey can be found in European Commission (2004b). Abramovsky et al. (2004b) provides a description of the surveys and sampling methodology in France, Germany, Spain and the UK.

Table 2.1. Characteristics of CIS3 in France, Germany, Spain and U.K.

	France	Germany	Spain	U.K.
Responsible national authority	INSEE for trade and services, SESSI for the manufacturing industry, Ministry of Research for R&D firms, Banks and Insurance companies, SCEES for the food industry[5]	ZEW (Centre for European Economic Research, on behalf of German ministry for technology and education)	INE (Instituto Nacional de Estadstica)	DTI (Department of Trade and Industry)
Participation	Compulsory	Voluntary	Compulsory	Voluntary
Target population (No of employees)	20 for the manufacturing industry, 10 elsewhere	5	10	10
Frame population[1]	Business Register	Credit reform database	Official INE register of firms (DIRCE)	Interdepartmental Business Register (IDBR)
Covered sectors[2]	C, D, E, G, I, J, K	C, D, E, F, G, I, J, K, O (only 90)	C, D, E, F, G, H, I, J, K, N, O	C, D, E, F, G (except 50,52), I, J, K
Stratification	Size, sectors	Size, sectors, region	Size, sectors	Size, sectors, region
Gross sample[3]	9,620	20,717	–	19,602
Net sample	7,836	4,611	11,778	8,172
Response rate	82%	22%	–	42%
Non-response analysis[4]	no	yes	no	yes

[1]A business register didn't exit in Germany. Credit reform is the largest German credit rating agency.

[2]According to NACE classification: C (mining and quarrying), D (manufacturing), E (electricity, gas and water supply), F (construction), G (wholesale, retail trade, repair of motor vehicles), H (hotels), I (transport, storage and communication), J (financial intermediation), K (real estate, renting and business activities), N (health and social work), O (other community, social and personal service activities).

[3]In France, the sampling rate varies by industry.

[4]Sample size of non-response in Germany: 4000.

[5]INSEE (Institut National de la Statistique et des Etudes Economiques), SESSI (Industrial Statistics Bureau of the Ministry of Industry), SCEES (Ministry of Agriculture).

Source: Abramovsky et al. (2004b).

CIS 3 is based on stratified samples of the total firm population in each country, typically applying disproportional drawing probabilities by size class and sector. While for most countries carrying out the CIS 3, participation in the survey is voluntary for firms (such as in Germany and the UK), some countries have set CIS3 as compulsory (such as France and Spain).

Net sample sizes (i.e. the number of firms returning a completed questionnaire) vary considerably among the four countries. Although Germany has the largest total population of firms, the net sample size is the lowest. This is caused by a small sampling frame due to financing restrictions of the German CIS survey and a low response rate as a result of voluntary participation combined with a general somewhat greater reluctance of German firms to participate in surveys. The largest net samples are available for France and Spain as a result of compulsory surveys. The sampling ratios range from 3.4 % (Germany), 7.9 % (UK) and 13.7 % (Spain) to 18.6% (France). In order to control for a response bias in the net sample, non-response analyses (NRA) have been carried out in Germany. A stratified random sample of firms in the gross sample that did not respond to the questionnaire was asked on a few questions relating to core innovation activities, using a computer-assisted telephone interview technique. The sample size of the NRA was about the same size as the net sample in order to compensate for the low sample ratio. According to the Eurostat methodology, the results of the NRA were used to adjust weighting factors for each responding firm in order to represent differences in the response behaviour of innovating and non-innovating firms.

I define firms that undertake cooperative innovative activity using the following question from the CIS3:

"*Did your enterprise have any cooperation arrangements on innovation activities with other enterprises or institutions during 1998-2000?*"[49]

In the questionnaire this is qualified to ensure that firms only answer "yes" where the cooperation agreement involves genuine collaborative innovative efforts rather than purely contracting out of R&D. If the firm responds positively, it is then asked to specify the types

[49] Question 8.1. Eurostat, Third Community Innovation Survey Harmonised Questionnaire.

of partner with whom they collaborated. Using this information I distinguish between three different types of external cooperative innovation arrangements[50]:

- *Cooperation with the research base*: cooperation arrangements with universities, government or private non-profit research institutes, and commercial laboratories or R&D enterprises.

- *Cooperation with suppliers or customers*: cooperation arrangements with customers or clients, or with suppliers of equipment, materials, components or software, (vertical cooperation).

- *Cooperation with competitors*: cooperation arrangements with competitors or other firms from the same industry, (horizontal cooperation).

The following two tables show the extent to which innovative firms in the four EU countries I consider undertake cooperative activity. Throughout the chapter I define innovative firms as "firms that have either introduced a product or process innovation, or have ongoing innovation activities or have abandoned innovation activities and have spent a positive amount on innovation activities during the period 1998-2000"[51]. In both tables I weight the data to be representative of the population of firms in each country. Table 2.A1 in Appendix 2.B contains information for the national samples.

In Table 2.2 I use a broad definition of cooperative activity that includes cooperation with suppliers and customers, with competitors and with the research base.

The table shows that the proportion of innovative firms undertaking any of these three forms of cooperative innovative activity is highest in France and the UK, followed by Germany and then Spain. Interestingly, in Germany and Spain there is little difference between the manufacturing and service sectors in the proportion of innovative firms engaging in cooperative activity, whereas in the UK and to an even greater extent in France, innovative

[50] I do not consider cooperation within the firm, i.e. across units belonging to the same enterprise group, because this type of collaboration is less relevant for policy.

[51] In the surveys for France, Germany and Spain it is only innovative firms that answer questions about cooperative innovative activity. Given the very broad definition of innovative firms used this should not present a selection problem. Indeed in the UK survey this information is available for all firms. I find that only around 4% of non-innovative firms reported that they were involved in cooperative innovative activities.

Table 2.2. Percentage of innovative firms with cooperation agreements by sector 1998-2000[1]

Sector	France	Germany	Spain	U.K.
Manufacturing	29%	19%	13%	25%
High-technology sectors	36%	28%	22%	32%
Low-technology sectors	24%	13%	10%	20%
Services	18%	17%	15%	20%
Total	26%	18%	14%	23%

[1]Calculations are weighted (using national CIS3 weights) to be representative of the population of innovative firms in each country. Populations are innovative firms with 20 or more employees. High-technology manufacturing sectors are defined as: Chemicals (NACE 23, 24), Machinery (29), Electronics, Computer equipment (30, 31, 32, 33), and Vehicles (34, 35). Low-technology manufacturing sectors are: Food and Tobacco (15, 16), Textiles (17, 18, 19), Wood and wood products (20, 21, 22), Plastics (25), Nonmetallic mineral products (26), Metallic mineral products (27, 28), Manufacturing n.e.c. (36, 37). Service sectors are: Wholesale trade (51), Transport (60, 61, 62, 63), Telecoms (64), Finance (65, 66, 67) Computer, R&D, and Other technical services (72, 73, 74.2, 74.3)

firms in the manufacturing sector are more likely to cooperate than those in the service sector. Within the manufacturing sector in all four countries on average innovative firms in high-tech manufacturing sectors such as chemicals, electronics and computer equipment are more likely to engage in cooperative activity than those in low-tech manufacturing sectors[52].

It is interesting to look at whether cross-country differences in the extent of overall collaborative activity are driven by differences in cooperative arrangements with specific partners.

Table 2.3 shows the percentages of innovative firms with different types of cooperative arrangements. In the UK and France the most common type of cooperative innovative activity is with suppliers or customers. In Spain the most common form of cooperative activity is with universities or research laboratories, and in Germany, cooperative activi-

[52]See Abramovsky et al. (2004b) for further international comparisons, including whether collaborative agreements are with national or international partners, and full sector-level breakdowns.

Table 2.3. Percentage of innovative firms with different types of cooperative agreements. 1998-2000[1]

Type of cooperative agreement	France	Germany	Spain	U.K.
Agreements with the research base				
Manufacturing	18%	13%	12%	16%
Services	10%	9%	10%	10%
Total	16%	11%	12%	14%
Agreements with suppliers or customers				
Manufacturing	21%	13%	7%	21%
Services	14%	11%	13%	18%
Total	19%	12%	9%	20%
Agreements with competitors				
Manufacturing	7%	6%	4%	4%
Services	5%	8%	6%	6%
Total	7%	7%	5%	5%

[1]Calculations are weighted (using national CIS3 weights) to be representative of the population of innovative firms in each country. Populations are innovative firms with 20 or more employees. Manufacturing and service sectors are defined as in Table 2.2.

ties with suppliers or customers and with universities or research laboratories are equally common. In line with the discussion in Section 2.2, I find that in all countries cooperation arrangements with competitors are the least frequent type of collaborative innovative activity. Despite the recent policy concern in the UK the proportion of innovative firms with cooperative arrangements with universities or research laboratories does not appear to be particularly low compared to the other countries.

Across all four countries cooperative arrangements with the research base appear to be more prevalent in the manufacturing sector than in the service sector. However when looking at business-to-business cooperation (both vertical and horizontal) in some countries these types of arrangements are more widespread in the service sector, in particular in the case of cooperative innovation arrangements with competitors.

I also looked briefly at whether, among innovative firms, those with cooperative innovation arrangements perform differently to those without. First, looking at labour productivity, I found that across all four countries in the manufacturing sector innovative firms that engaged in cooperative innovation tended to have higher labour productivity than those that did not. Those that entered into cooperative agreements also reported that a higher proportion of their sales were due to innovative products introduced between 1998 and 2000. While these performance characteristics may be the direct outcome of undertaking cooperative innovation, it may also be the case that these types of firms are more likely to enter into cooperative agreements in the first place[53]. In the service sector the picture was more mixed, for example there was no clear correlation between labour productivity and cooperative activity.

2.3.1. Characteristics of innovative firms that engage in cooperative innovation

The characteristics I focus on in my analysis are measures of incoming spillovers, appropriability, constraints on innovation (a combination of cost and risk factors that hamper innovation), and whether or not firms received financial public support for innovative activities. I also control for firm R&D intensity and size. I use information from the CIS3 survey to construct firm-level and industry-level variables. For comparability, as far as possible, I construct my variables in line with those used in CV[54,55]. In what follows I define the

[53] In the analysis below, I include a firm-level measure of R&D intensity to control for the firm's innovative capabilities and absorptive capacity.

[54] I have modified the variable definitions in CV in some cases in order to construct measures that are comparable across the four countries in the current study. For example, when measuring appropriability I use a count of the number of protection methods used (rescaled between zero and one) rather than using information on the intensity of use (rescaled between zero and one), which was not available in all four countries. However, for the countries where the full information was available I checked that constructing the appropriability variable in this way does not change the overall pattern of results.

[55] Variable definitions are similar to those used in Chapter 1. I have modified the variable definitions in some cases in order to construct measures that are comparable across the four countries.

main variables and present some descriptive statistics. A full set of definitions is provided in Appendix 2.A.

I measure the extent of incoming spillovers by a continuous variable bounded between 0 and 1, where a higher value implies that firms placed more value on public sources of information in carrying out their innovation activities. The measure is derived from a question that asks firms to rate the importance of different information sources for their innovation activity during the period 1998-2000. The information sources considered include professional conferences, meetings, journals or technical/trade press and fairs and exhibitions.

My measure of appropriability is based on information on the extent to which firms use strategic methods to protect their innovations. The question firms are asked is, "*During the period 1998-2000, did your enterprise, or enterprise group, make use of any of these methods to protect inventions or innovations developed in your enterprise?*"[56]. The strategic methods I consider are secrecy, complexity of design and lead-time advantage on competitors. This measure is again scaled between 0 and 1 and is increasing in the number of the methods used. Higher values indicate that firms faced greater appropriability problems. I also construct an industry-level measure of the extent of use of different legal protection methods such as patents and trademarks. This takes the form of an index measure between 0 and 1, which increases in the number of methods used and captures the scope for using formal protection methods to appropriate the returns to innovative activity.

I construct a measure that combines the extent to which firms are hampered in their innovation activities by cost and risk factors. This variable is called constraints and includes the extent to which the availability and cost of finance and excessive perceived risks impeded firms' ability to innovate. The index measure varies between 0 and 1 and is increasing in the extent to which these factors are declared to impose a constraint. CV include measures of the cost and risk factors separately. But in order to construct comparable variables across countries I have had to combine this information into a single measure. The precise variable

[56] CV base their measure on how firms rate the effectiveness of these methods, but unfortunately this is not how the question is phrased in CIS3, which increases concerns about endogeneity with regard to this variable.

used for the French analysis is slightly different, due to a difference in the questionnaire in France. It takes a value of 1 if the firm was constrained in its innovation activities and 0 otherwise.

I also construct a measure of whether firms received public support for innovation activities (public support). This is an indicator variable that takes the value 1 if the firm has received any kind of public financial support for innovation activities from local or national sources and takes the value 0 otherwise. Note that this public support need not have been directed specifically at cooperative innovative activity.

I include two further firm characteristics as controls. First, I construct a measure of the firm's internal innovative activity and absorptive capacity. The variable is called R&D intensity, and is defined as the ratio of intramural (internal) R&D expenditure to turnover in the year 2000[57]. It should be noted that this variable will also capture R&D expenditure on any collaborative project. Second, I construct a measure of firm size defined as the log of the number of employees.

Table 2.4 presents the sample mean values, for both firms that engage in cooperative innovative activity and for those that do not, for each of the variables that I consider. Within countries the mean values of all variables are significantly different across cooperative and non-cooperative firms. The only exception is that for the UK, there is only a weakly significant difference (at the 10% level) between the two groups in terms of the extent to which they perceive constraints (cost and risk factors) to be a barrier to innovative activity, however in the other three countries those firms that undertook cooperative innovation appeared to be significantly more constrained by these factors.

Across all four countries, firms with cooperation arrangements typically place greater importance on incoming spillovers (incoming spillovers), and on the use of strategic methods

[57] Ideally I would like to use a measure for 1998, but this was not possible due to large numbers of missing values in the data. However it is likely that firms' R&D expenditures are highly persistent. In CV, firms' internal R&D capabilities were measured by a dummy variable that took the value of 1 if a firm engaged in R&D on a continuous basis. CV also used a measure of whether the firm lacked technological know-how. I omit this variable, as it is not available in the French data. However, it is generally not significant when included in the regressions for the other three countries.

Table 2.4. Characteristics of cooperative (C) and non-cooperative (NC) innovative firms. Mean values[1]

	France		Germany		Spain		U.K.	
	C	NC	C	NC	C	NC	C	NC
Number of observations	1,286	2,304	408	775	612	2135	324	821
% of total observations	36%	64%	34%	66%	22%	78%	28%	72%
Incoming spillovers	0.40	0.28	0.58	0.53	0.49	0.42	0.43	0.36
Appropriability	0.37	0.19	0.57	0.34	0.41	0.26	0.79	0.66
Industry level legal protection	0.25	0.24	0.28	0.22	0.18	0.17	0.46	0.42
Constrains[2]	0.34	0.19	0.61	0.54	0.52	0.45	0.51	0.47
Public support	0.44	0.18	0.63	0.26	0.60	0.31	0.23	0.09
R&D intensity	0.05	0.02	0.06	0.02	0.08	0.02	0.03	0.01
Size	5.67	4.86	5.46	4.96	2.32	2.00	5.19	4.78

[1]The sample in each country comprises innovative firms in both manufacturing and service sectors defined as in Table 2.2. C = cooperating firms, NC = non cooperating firms.

[2]For France, dummy =1 if firm is constrained.

for appropriating the returns to innovation (appropriability) and are typically in industries where greater importance is placed on legal methods of protecting the returns to innovation. Firms that engage in cooperative innovative activity also exhibit higher R&D intensity and are on average larger than those that do not. These findings are also in line with those in CV for Belgian manufacturing firms. Firms that undertake cooperative innovation are also more likely to receive public support.

I also looked at whether there were significant differences in the mean values of these variables across countries within the two categories of firms – e.g. comparing cooperative firms in France with cooperative firms in Germany. I find that in the vast majority of cases there are significant differences across countries. For example, firms in Germany that have cooperative innovation arrangements place more importance on incoming spillovers than those in Spain, the UK and France. Innovative firms in the UK, both those that engage in cooperative innovation and those that do not, place more importance on strategic methods of protection (appropriability), and formal methods of protection than their counterparts in Germany, France and Spain. Among cooperative innovative firms R&D intensity is highest in Spain and lowest in the UK. The proportion of cooperative innovative firms that receive public support for innovation is highest in Germany and Spain at around 60% and significantly lower in the UK at just over 20%. Indeed innovative firms in France, Germany and Spain that were not involved in cooperative innovation were also more likely to receive public support than non cooperating firms in the UK.

2.4. Empirical results

Before presenting instrumental variables estimates, I first examine the relationship between these characteristics and the likelihood of cooperation by estimating a probit model for each country, where the dependent variable takes on a value of one if the firm is engaged in a cooperative agreement. Table 2.5 shows the results of this exercise. The figures shown are the marginal effects of each of the explanatory variables on the probability of undertaking a cooperative agreement. For each country I also include, as an explanatory variable, an industry-level measure of the extent of cooperative activity, to control for unobserved industry characteristics associated with this decision.

In all four countries, conditional on other factors, firms that use strategic protection methods (appropriability) were more likely to be engaged in cooperative innovative activity, which is in line with the findings in CV. Also, in all countries I find a positive association between the likelihood that firms have received financial public support and the probability of being engaged in cooperative innovative activities. In the UK and France I find that firms that are involved in cooperative arrangements place greater importance on incoming knowledge spillovers in their innovative activities, however the results are not statistically significant for Germany and Spain.

Turning to the measures of the extent to which constraints such as cost and risk factors are perceived as an obstacle to innovative activity, I find that in particular in Spain and France

Table 2.5. Characteristics of firms that have cooperative innovation arrangements

Dependent variable = 1 if firm has a cooperative arrangement				
	France	Germany	Spain	U.K.
Incoming spillovers	0.242***	0.009	0.031	0.174***
	(0.032)	(0.056)	(0.026)	(0.062)
Appropriability	0.195***	0.242***	0.079***	0.078**
	(0.025)	(0.040)	(0.018)	(0.038)
Industry level legal protection	0.101	-0.195	-0.040	-0.133
	(0.178)	(0.215)	(0.131)	(0.147)
Constrains	0.090***	0.101*	0.104***	0.053
	(0.021)	(0.055)	(0.026)	(0.055)
Public support	0.227***	0.313***	0.151***	0.231***
	(0.020)	(0.031)	(0.017)	(0.046)
R&D intensity	0.186***	0.638*	0.180**	0.371
	(0.087)	(0.344)	(0.089)	(0.251)
Size	0.004	0.126***	0.342***	0.022
	(0.044)	(0.050)	(0.083)	(0.740)
Size squared	0.007*	-0.005	-0.038**	0.002
	(0.004)	(0.004)	(0.017)	(0.007)
Industry level of cooperation	0.699***	0.744***	0.733***	0.943***
	(0.071)	(0.160)	(0.071)	(0.178)
LL	-1,910.54	-599.16	-1,171.87	-611.57
No. observations	3,590	1,183	2,747	1,145

***significant at 1% level, **significant at 5% level, *significant at 10% level. The numbers reported are the marginal effect of the independent variable on the probability of cooperation. Standard errors in parentheses.

firms engaged in cooperative research are more likely to see these factors as hampering innovation. Finally, firms are more likely to be engaged in cooperative arrangements the higher their R&D intensities, although this variable is not significant in the case of the UK. There is also evidence for Germany and in particular for Spain that larger (although not necessarily the largest) firms are more likely to engage in cooperative innovation.

As discussed above there are reasons to believe that the variables appropriability, incoming spillovers, constraints and R&D intensity are endogenous. In the next section I present instrumental variables estimates, following the approach applied in CV to attempt to control for potential endogeneity bias.

2.4.1. Instrumental variables results

I consider the variables incoming spillovers, appropriability, constraints and R&D intensity as potentially endogenous due to simultaneity or reverse causality. For example, following the discussion in Section 2.2, in the case of constraints it may be that cooperative agreements alleviate constraints that were present ex-ante[58]. I attempt to deal with the problem of endogeneity using a two-step approach. First the potentially endogenous explanatory variables are regressed on a set of (assumed) exogenous variables. The predicted values of the potentially endogenous variables are obtained from the first step regression and are used in place of the endogenous variables in the second step regression.

I use the same set of assumed exogenous variables as CV as instruments. The instrument set includes industry-level measures of the potentially endogenous variables, i.e. incoming spillovers, appropriability, constraints and R&D intensity. These are intended to capture the effect of unobserved industry-specific attributes related to the specific endogenous variables, but not to the probability of cooperating, at the 2-digit level. It also includes a firm-level measure of export intensity (exports as a proportion of total sales). This aims to

[58] See Chapter 1 and López (2008) for a detailed discussion of the problem of endogeneity. Schmidt (2005) considers this issue in the context Germany. For an analysis of R&D cooperation in France using the CIS2 see Miotti and Sachwald (2003).

capture the intensity of competition which firms face, thought to be highly correlated with appropriability conditions – higher competition being associated with lower appropriability, and a greater reliance on strategic protection methods. In addition, I also include a firm-level measure of the extent to which the firm's R&D activity is orientated towards basic research. This is derived from questions on the extent to which firms source information for research activities from the research sector (see Appendix 2.A). I might expect this variable to be positively correlated with a firm's innovative capabilities (R&D intensity) and absorptive capacity and the extent to which they can capitalise on incoming spillovers more generally. Finally, the instrument set contains the (assumed) exogenous variables included in the second step regressions, such as firm size, the industry level of legal protection and industry level of cooperation. The results of the first step regressions are given in Table 2.A2 in Appendix 2.B[59,60].

Table 2.6 shows the results of the second step regressions for the national samples.

Comparing the results in Table 2.6 for general cooperation to the results from the simple probit estimation in Table 2.5, it can be seen that the marginal effects of the incoming spillovers and the appropriability variables increase substantially in the IV specifications –

[59] I use the same assumed exogenous instrument set as CV. Since the variables are contemporaneous this may be a strong assumption, but it is difficult to find a set of truly exogenous and powerful instruments in the CIS data. For example the measure of the extent to which a firm's R&D activity is orientated towards basic research may be influenced by their decision to cooperate with the research base. As shown in Table 2.A2, this variable is important for the power of our instruments. If it is excluded, the statistical significance, and in some cases the magnitude, of the estimated coefficients is affected. For example, for cooperation with the research base in the case of the UK, the marginal effects (standard errors) on the incoming spillovers, appropriability and legal protection variables become 0.117 (0.405), 0.224 (0.157), -0.227 (0.145) respectively, compared to those in table 6, (the marginal effects and significance of the other variables are unaffected). Also, as noted by CV, the IV approach used could introduce multicollinearity between the predicted values of the endogenous variables, reducing the significance of the estimated coefficients.

[60] It should be noted that the original explanatory endogenous variables exhibit firm-level variation as well as industry-level variation. In the first step regressions it can be seen that in some cases a substantial amount of the predictive power for each variable's fitted value comes from the industry-level variables. This means that the fitted values provide more industry variation than firm-level variation.

Table 2.6. Understanding cooperative innovative activity.

Second-step results

Dependent variable = 1 if firm has a cooperative arrangement				
	France	Germany	Spain	U.K.
Incoming spillovers (I)	0.854***	1.214***	0.575***	0.633***
	(0.107)	(0.244)	(0.106)	(0.196)
Appropriability (I)	0.358**	0.456***	0.438***	0.252
	(0.168)	(0.191)	(0.134)	(0.180)
Industry level legal protection	-0.092	-0.759***	-0.744***	-0.248
	(0.195)	(0.285)	(0.184)	(0.186)
Constrains (I)	0.115	-0.410	0.357**	-0.066
	(0.163)	(0.350)	(0.163)	(0.330)
Public support	0.149***	0.340***	0.071***	0.228***
	(0.023)	(0.038)	(0.017)	(0.047)
R&D intensity (I)	-0.410**	-0.788	-0.067	-0.585
	(0.205)	(0.482)	(0.149)	(0.663)
Size	-0.001	0.046	0.331***	-0.040
	(0.045)	(0.059)	(0.093)	(0.076)
Size squared	0.006	-0.001	-0.039**	0.006
	(0.004)	(0.005)	(0.018)	(0.007)
Industry level of cooperation	0.674***	1.044***	0.782***	0.972***
	(0.085)	(0.223)	(0.091)	(0.199)
LL	-1,900.34	-592,22	-1,087.92	-606.20
No. observations	3,590	1,183	2,747	1,145

***significant at 1% level, **significant at 5% level, *significant at 10% level.

The numbers reported are the marginal effect of the independent variable on the probability of cooperation. Standard errors in parentheses. (I) indicates instrumented.

though appropriability is insignificant for the UK. The increase in the marginal effects could be due to endogeneity bias, or potentially due to measurement error. For example, the fact that the marginal effect on the incoming spillovers variable increases after instrumenting suggests that firms that ex-ante place more importance on the use of publicly available information are more likely to benefit from cooperative arrangements, but once such firms are engaged in cooperative innovation they may substitute the use of publicly available information for information generated within the partnership and hence place less importance on other external knowledge.

Findings for the effects of incoming spillovers and appropriability show very few departures from the original findings in CV for Belgium. However I find some evidence, contrary to the findings in CV, that cooperation is less likely in industries where legal methods of protecting innovations are more effective. Taking this together with the findings on appropriability for France, Germany and Spain, it may be that cooperative activity is a method of internalising outgoing knowledge flows in industries where legal protection methods are weak and for firms for whom more strategic methods of appropriating returns are more important.

A further point to note is that after instrumenting I find no statistically significant relationship between the perception of cost and risk constraints and cooperative innovation, apart from in Spain. The marginal effect on this variable increases in the case of Spain, and I might have expected the marginal effects to be biased downwards in Table 2.5 had cooperative R&D activity been undertaken in order to alleviate cost and risk constraints. It is also only in the case of Spain where I find that firm size is positively related to the probability of undertaking cooperative innovation.

After instrumenting, the marginal effects on the R&D intensity variable decrease compared to Table 2.5. I do not find that higher intramural R&D intensity increases the likelihood of engaging in cooperative innovative activities amongst innovative firms. Indeed, if anything the results for France suggest the opposite. It may be that ex-ante firms choosing to collaborate perceive cooperative innovation as a substitute for carrying out R&D activity purely in house – those firms with strong internal capabilities may have less need to engage in collaborative innovation. I explore what is driving this finding when I differentiate between cooperative innovative activities with different partners and between cooperation in the manufacturing and service sectors below. Finally, in all cases I continue to find a positive relationship between having received public financial support and the likelihood of cooperating.

Cooperation with different partners

Table 2.7 shows the results for cooperation with each of the three different partners - the research base, customers and suppliers, and competitors. The findings in CV for Belgium suggest that incoming spillovers are an important factor in determining cooperation with research institutions, but not vertical cooperation with suppliers or customers, and that while appropriability is an important factor in determining vertical cooperation, it is not for cooperation with research institutes.

Findings for incoming spillovers are in line with those in CV. I find that the extent to which firms value incoming spillovers is positively associated with the probability of undertaking collaborative research with universities, and that the relationship is stronger with respect to cooperation with the research base than with other firms. This indicates that being able to benefit from external information flows is a more important determinant of whether a firm enters into a collaborative agreement with the research base compared to a potentially more 'near market' or developmental commercial agreement with another business. Indeed, there is a stronger relationship between incoming spillovers and the likelihood of vertical cooperation than horizontal cooperation, implying a stronger link between the value firms place on external information flows and the probability of cooperating with firms outside the same industry, which are likely to possess a more diverse set of knowledge.

Table 2.7. Understanding different types of cooperative innovative activity by partner. Second-step results

	Dependent variable = 1 if firm has a cooperative arrangement with the research base				Dependent variable = 1 if firm has a cooperative arrangement with suppliers or customers				Dependent variable = 1 if firm has a cooperative arrangement with competitors			
	France	Germany	Spain	U.K.	France	Germany	Spain	U.K.	France	Germany	Spain	U.K.
Incoming spillovers (I)	0.888***	1.354***	0.492***	0.647***	0.495***	0.517**	0.294***	0.419**	0.271***	0.299**	0.159***	0.172**
	(0.086)	(0.231)	(0.094)	(0.152)	(0.091)	(0.204)	(0.083)	(0.175)	(0.052)	(0.139)	(0.052)	(0.080)
Appropriability (I)	0.122	0.577***	0.468***	0.330**	0.378**	0.320***	0.301***	0.222	0.003	0.097	0.149**	0.092
	(0.140)	(0.143)	(0.113)	(0.142)	(0.144)	(0.120)	(0.103)	(0.161)	(0.090)	(0.089)	(0.067)	(0.078)
Industry level legal protection	-0.252	-0.636***	-0.617***	-0.270**	-0.123	-0.379*	-0.478***	-0.172	-0.055	-0.304**	-0.200**	-0.085
	(0.160)	(0.263)	(0.161)	(0.130)	(0.170)	(0.196)	(0.147)	(0.163)	(0.100)	(0.124)	(0.101)	(0.073)
Constrains (I)	0.304**	-0.299	0.485***	-0.009	0.047	-0.286	0.218*	-0.049	0.068	0.093	0.164*	-0.055
	(0.138)	(0.340)	(0.152)	(0.240)	(0.138)	(0.286)	(0.129)	(0.305)	(0.085)	(0.211)	(0.091)	(0.146)
Public support	0.125***	0.363***	0.059***	0.214***	0.075***	0.153***	0.043***	0.149***	0.032**	0.106***	0.015	0.021
	(0.021)	(0.038)	(0.015)	(0.044)	(0.021)	(0.034)	(0.014)	(0.044)	(0.013)	(0.026)	(0.009)	(0.022)
R&D intensity (I)	-0.341**	-0.869***	-0.061	-0.267	-0.265	-0.551*	-0.085	-0.829	-0.095	-0.270	-0.039	-0.442
	(0.164)	(0.383)	(0.115)	(0.460)	(0.174)	(0.321)	(0.128)	(0.554)	(0.095)	(0.215)	(0.059)	(0.431)
Size	0.033	0.029	0.315***	-0.000	0.039	0.020	0.227***	-0.032	-0.022	-0.004	0.098**	-0.035
	(0.034)	(0.051)	(0.081)	(0.052)	(0.035)	(0.048)	(0.072)	(0.066)	(0.017)	(0.031)	(0.046)	(0.031)
Size squared	0.002	-0.001	-0.040***	0.001	0.001	0.001	-0.026*	0.004	0.003**	0.002	-0.008	0.004
	(0.003)	(0.004)	(0.016)	(0.005)	(0.003)	(0.004)	(0.014)	(0.006)	(0.002)	(0.002)	(0.008)	(0.003)
Industry level of specific type	0.627***	0.743***	0.641***	0.597***	0.557***	0.992***	0.672***	0.996***	0.534***	0.707***	0.493***	0.550***
of cooperation	(0.067)	(0.194)	(0.078)	(0.122)	(0.104)	(0.210)	(0.105)	(0.196)	(0.047)	(0.151)	(0.076)	(0.175)
LL	-1,400.25	-436.10	-945.11	-408.28	-1,825.06	-546.41	-940.52	-568.86	-1,029.92	-379.17	-658.83	-218.84
No. observations	3,590	1,183	2,747	1,145	3,590	1,183	2,747	1,145	3,590	1,183	2,747	1,145

***significant at 1% level, **significant at 5% level, *significant at 10% level. The numbers reported are the marginal effect of the independent variable on the probability of cooperation. Standard errors in parentheses. (I) indicates instrumented.

Findings for appropriability differ somewhat from those in CV. I find evidence that firms facing appropriability problems, (i.e. firms that are more reliant on strategic protection methods such as secrecy), are more likely to engage in collaborative innovation with the research base and with suppliers and customers. However, the relationship is much less evident for cooperation with competitors. The magnitude of the estimated marginal effects is much smaller for this type of partner, and only statistically significant in the case of Spain. Limiting outgoing spillovers to direct competitors might be much more important compared to limiting information flows to upstream or downstream firms or noncommercial research institutions.

Hence the fact that the evidence does not point towards firms facing appropriability problems as being likely to engage in collaborative projects with competitors is in line with the idea that free-riding might be more prevalent in this type of cooperative relationship.

Turning to the relationship between constraints and collaborative innovative activity, I find that for Spain and to a lesser extent for France, for all three types of partner it is those firms that report being constrained in their innovation activity, for example due to financial constraints, that are more likely to be engaged in cooperative innovative activity. Furthermore, I find that the relationship is stronger and more significant for cooperation with the research base, in fact for France this is the only case where it is significant. This may be due to the type of projects undertaken in conjunction with the research base being riskier, or more difficult to obtain external finance for, than those typically undertaken with other firms.

Receipt of public support is positively related to the probability of cooperating with all three types of partners in Germany and France and Spain, but in the UK I find no relationship with the probability of cooperating with competitors[61]. In all countries the marginal effects are highest with regard to cooperating with the research base. This finding is consistent with the aims of policy in this area in terms of encouraging cooperation between firms and universities and facilitating technology transfer from the public sector, and reflects

[61] See also the study by Negassi (2004), which finds a positive effect of public funding on the likelihood of cooperation on innovation activities.

the focus of the policies in operation in all four countries.

For example, in France, the Ministry of Research puts a lot of emphasis on developing R&D cooperation between the public and private sectors. There are two main forms of support: the RRIT (R&D and Technology Innovation Networks), which aim to improve partnerships between public sector R&D and firms – there were 15 at the end of 2004; and the CNRTs (National Centres of Technological Research), which support collaboration between public R&D labs and labs in large manufacturing firms - 18 centres have been created since 2000[62]. Since 1980 Germany has seen a significant rise in the proportion of publicly funded R&D projects that involve collaborative networks (from around 30% of spending in 1980-89 to nearly 90% by 2004), which has been driven by a substantial increase in publicly funded projects that involve collaboration between business and scientific research institutions[63]. In Spain, the National R&D plan was adopted in 1988. One of the instruments of technology policy included in this plan is known as the Industrial Research Concerted Projects. The objective of this national initiative is to finance precompetitive research projects developed by industrial firms, which must include the participation of universities, public research centers or research and technology organisations[64]. In the UK during the period covered by data (1998 to 2000), the LINK and Faraday Partnerships schemes provided grant-based funding for research consortia including university partners, for research into pre-market areas and technology transfer.

Turning briefly to the other control variables, in France and Germany evidence suggests that firms with lower intramural R&D intensity are actually more likely to engage in cooperative innovation with the research base. This might imply that they are doing so to access expertise that they do not have in-house at a lower cost. For Spain I also find a significant relationship between firm size and the likelihood of undertaking cooperative innovation with all three types of partner.

[62] See MNRT (2005) for further details.

[63] See Fier et al. (2006) for further details.

[64] See Acosta and Modrego (2001) for further details.

Differences between manufacturing and services

As a final exercise I looked at the manufacturing and service sectors separately to see if any of the relationships above differed across the two sectors and whether there were any interesting differences across countries within each of the two sectors. I detail the main points of interest below.

First, finding in Table 2.6 that in Germany and Spain cooperation is less frequent in industries where legal protection methods are used more intensively is largely driven by the manufacturing sector. This pattern of a negative relationship with the extent of industrylevel legal protection in manufacturing sectors but not in services is common across all four countries, and suggests that whereas cooperative innovation may act as a substitute to patenting innovations in the manufacturing sector, it may not be used as a substitute to formal protection methods such as trademarks and copyright in the service sector.

There are also some interesting differences within and across sectors between the four countries. First, there is some evidence that appropriability problems, i.e. greater reliance on strategic protection methods, are less important in influencing cooperative innovation in the service sector than in manufacturing in France, Germany and the UK, but are important in both sectors in Spain. Second, in the UK and to a lesser extent in France, the significant positive correlation between public support and the probability of cooperation is only present for firms in the manufacturing sector and not for firms in the service sector. For the UK, this again fits in with the orientation of policy at this time towards collaboration with the research base on basic research and new technologies, which are more likely to be of direct relevance to manufacturing firms. Third, the negative (although in some cases insignificant) relationship in Table 2.6 between R&D intensity and the likelihood of cooperation appears to be largely driven by the service sector in all countries except for France, implying that cooperative innovation and intramural R&D intensity might be substitutes to a greater extent in the service sector than in manufacturing in Spain, Germany and the UK.

Finally, in Spain the positive and significant relationship between the importance of constraints (as hampering factors for innovation) and cooperation in Table 2.6 is largely driven by the manufacturing sector. I find that this relationship disappears for services. Moreover, firm size is only statistically significant for the manufacturing sector in Spain.

2.5. Conclusions

I investigate the determinants of cooperative innovative activity using comparable firm-level data for four major EU economies. I find evidence of a positive relationship between the extent to which firms are able to benefit from external information flows, i.e. from incoming spillovers, and the likelihood of undertaking cooperative innovation. This is strongest with respect to collaboration with the research base and weakest with respect to cooperation with competitors in the same industry, suggesting that firms that place a high value on external information flows are more likely to collaborate with firms outside their own industry or with research institutes, enabling them to access a broader range of knowledge.

I also find some evidence that firms that find strategic methods important in appropriating the returns to innovative activity, i.e. those facing appropriability problems, are more likely to make cooperative arrangements with the research base and with upstream and downstream firms. The estimated relationship is weaker for cooperation with competitors, implying that for firms facing appropriability difficulties free-riding may be more problematic within agreements with other firms operating in the same market.

Findings for Spain differ to some extent from those for Germany and the UK. In Spain I find that, particularly in the manufacturing sector, larger firms are more likely to engage in cooperative innovation, and that firms may be undertaking cooperative innovation in order to overcome financial constraints and excessive perceived economic risks, (I also find some evidence of this for France in the case of cooperation with the research base). This may be driven by differences in capital markets and in the availability and cost of external private finance for innovative activity, between Spain and the other countries. For example, in 2001 venture capital investment in Spain was approximately one third of investment in Germany or in the UK. Moreover, Loan Guarantee Programs are not well developed in Spain[65].

[65] Cotec (2004) and European Commission (2003).

Finally I find that receipt of public support is positively related to the probability of undertaking cooperative innovation particularly with regard to cooperation with the research base, for example with universities and public sector research institutions. This is very much in line with the orientation of public funding for innovation, which targets this type of cooperative activity and promotes technology transfer from universities to business. The relationship between receipt of public support and collaborative innovation is weakest for cooperation with competitors. This is not surprising given that this type of cooperation might be the most likely to raise concerns with competition policy authorities, and given that public support schemes are much less orientated towards this form of collaboration.

Although I find a positive relationship between cooperation and public financial support, it is not possible to make definitive statements about the size of additionality of such schemes using my results. It maybe that at least some of those firms receiving support would have engaged in some form of cooperative innovation (albeit perhaps on a smaller scale) in any case. The extent to which such schemes do overcome market failures and enable additional and economically efficient cooperative innovative activity to take place is an important research question given the direction of public policy in this area.

Appendix 2.A. Variable definitions

Absolute basicness of R&D: Sum of the scores of the importance of the following information sources for innovation process (number between 0 (not used) and 3 or 4 (high)): universities; government or private non-profit research institutes. Rescaled between 0 (not used) and 1 (high).

Appropriability: Sum of indicator variables that take the value 1 if the firm uses the following methods for protecting inventions or innovations (0 (not used) and 1 (used)): secrecy; complexity of design; lead-time advantage on competitors. Rescaled between 0 (not used) and 1 (used all methods).

Cooperation: Indicator variable that takes the value 1 if the firm cooperates with suppliers, customers, competitors or other firms within the same industry, universities, government or private non-profit research institutes, or commercial laboratories/R&D enterprises.

Cooperation with competitors: Indicator variable that takes the value 1 if the firm cooperates with competitors or other firms within the same industry.

Cooperation with research base: Indicator variable that takes the value 1 if the firm cooperates with universities, government or private non-profit research institutes, or commercial laboratories or R&D enterprises.

Cooperation with suppliers or customers: Indicator variable that takes the value 1 if the firm cooperates with suppliers or customers.

Constraints: Importance of the following obstacles to the innovation process (number between 3 or 4 (high) and 0 (not relevant)): innovation costs too high; lack of availability of finance; excessive perceived economic risks. Rescaled between 0 (not relevant) and 1 (high). The questions used to construct the variable constraint are not available in the French survey. Hence, for the French case I use an alternative indicator variable that takes the value 1 if the firm considers that innovation activity was burdened/encumbered with serious problems.

Export intensity: Exports divided by turnover in 2000.

Incoming spillovers: Sum of the scores of the importance of the following information sources for innovation process (number between 0 (not used) and 3 (high)): professional conferences, meetings and journals; fairs and exhibitions. Rescaled between 0 (not used) and 1 (high).

Industry level of legal protection: Mean of legal protection at the industry level. Legal protection is the sum of indicator variables that take the value 1 if the firm uses the following methods for protecting inventions or innovations (0 (not used) and 1 (used)): patents; registration of design patterns; trademarks; copyright. Rescaled between 0 (not used) and 1 (used all methods).

Industry level of variable: Mean of the variable at the 2-digit NACE level.

Public support: Variable that takes the value 1 if the firm has received any kind of public financial support for innovation activities from local or national sources.

R&D intensity: Ratio of intramural R&D expenditure in 2000 over turnover in 2000.

Size: Log of number of employees in 2000.

Industries included in the analysis

Description	*NACE Code*
Manufacturing	
Food and tobacco	15, 16
Textiles	17, 18, 19
Wood and wood products	20, 21, 22
Chemicals	23, 24
Plastics	25
Non-metallic mineral products	26
Machinery	29
Electronics and computer equipment	30, 31, 32, 33
Vehicles	34, 35
Metallic mineral products	27, 28
Manufacturing n.e.c.	36, 37
Services	
Wholesale trade	51
Transport	60, 61, 62, 63
Telecoms	64
Finance	65, 66, 67
Computer, R&D, other technical services	72, 73, 74.2, 74.3

Appendix 2.B. Additional tables

Table 2.A1. Percentage of innovative firms with different types of cooperative agreements. National samples. 1998-2000[1]

	France	Germany	Spain	U.K.
Innovative firms	3,590	1,183	2,747	1,145
Cooperating	1,286	408	612	324
(as % innovative firms)	*(36%)*	*(34%)*	*(22%)*	*(28%)*
Cooperating with the research base	859	317	533	200
(as % innovative firms)	*(24%)*	*(27%)*	*(19%)*	*(18%)*
Cooperating with customers or suppliers	973	268	427	265
(as % innovative firms)	*(27%)*	*(23%)*	*(15%)*	*(23%)*
Cooperating with competitors	359	146	242	67
(as % innovative firms)	*(10%)*	*(12%)*	*(9%)*	*(6%)*

[1]Figures calculated from the CIS3 sample for each country. Firms with more than 20 employees. The total number of innovative firms reported in this table is smaller than the total sample of innovative firms in each country as I only include those with non-missing values for the variables used in the subsequent analysis.

Table 2.A2. Results of first step OLS regressions: Incoming spillovers and Appropriability

	Dependent variable: Incoming spillovers				Dependent variable: Appropriability			
	France	Germany	Spain	U.K.	France	Germany	Spain	U.K.
Size	0.019	0.016	-0.144***	0.088***	-0.019	0.004	0.037	0.095*
	(0.018)	(0.023)	(0.052)	(0.032)	(0.022)	(0.037)	(0.085)	(0.053)
Size squared	-0.002	-0.001	0.024**	-0.007**	0.005**	0.004	0.002	-0.006
	(0.002)	(0.002)	(0.010)	(0.003)	(0.002)	(0.003)	(0.018)	(0.004)
Industry level legal protection	0.053	0.144	0.109	-0.044	0.047	-0.443*	0.110	-0.105
	(0.096)	(0.159)	(0.182)	(0.104)	(0.110)	(0.232)	(0.259)	(0.197)
Public support	0.028***	-0.019	0.033***	-0.016	0.077***	0.019	0.013	-0.025
	(0.010)	(0.017)	(0.011)	(0.017)	(0.014)	(0.022)	(0.016)	(0.032)
Absolute basicness of R&D	0.479***	0.298***	0.387***	0.508***	0.224***	0.182***	0.189***	0.328***
	(0.020)	(0.030)	(0.021)	(0.034)	(0.027)	(0.041)	(0.030)	(0.062)
Export intensity	-0.035**	0.008	-0.027	-0.016	0.100***	0.258***	0.150***	0.078**
	(0.017)	(0.034)	(0.022)	(0.022)	(0.024)	(0.049)	(0.032)	(0.039)
Industry level of cooperation	-0.154***	-0.227**	-0.111	-0.106	-0.324***	-0.188	-0.107	-0.105
	(0.051)	(0.103)	(0.069)	(0.087)	(0.066)	(0.138)	(0.089)	(0.163)
Industry level incoming spillovers	0.843***	1.004***	0.867***	0.663***	0.015	-0.045	0.011	-0.286
	(0.147)	(0.171)	(0.118)	(0.210)	(0.178)	(0.239)	(0.153)	(0.398)
Industry level appropriability	0.034	-0.147	-0.094	-0.059	1.109***	1.203***	0.774***	0.969***
	(0.094)	(0.122)	(0.144)	(0.092)	(0.109)	(0.164)	(0.193)	(0.189)
Industry level R&D intensity	-0.347***	0.135	-0.143	-0.078	-0.050	0.366	0.042	0.143
	(0.127)	(0.222)	(0.109)	(0.300)	(0.174)	(0.301)	(0.149)	(0.458)
Industry level constraints	-0.054	-0.035	-0.146	-0.091	-0.008	-0.094	0.039	-0.048
	(0.074)	(0.147)	(0.110)	(0.133)	(0.096)	(0.177)	(0.140)	(0.249)
Constant	-0.023	0.027	0.255***	-0.064	-0.054	-0.050	-0.121	-0.132
	(0.062)	(0.112)	(0.089)	(0.125)	(0.077)	(0.151)	(0.210)	(0.210)
R^2	0.20	0.13	0.16	0.21	0.13	0.21	0.08	0.15
No. observations	3,590	1,183	2,747	1,145	3,590	1,183	2,747	1,145

***significant at 1% level, **significant at 5% level, *significant at 10% level. Standard errors in parentheses.

Table 2.A2 (continued). Results of first step OLS regressions: Constraints and R&D intensity

	Dependent variable: Constraints				Dependent variable: R&D intensity			
	France	Germany	Spain	U.K.	France	Germany	Spain	U.K.
Size	-0.005	-0.054**	-0.231***	-0.022	0.002	-0.007	-0.026*	0.006
	(0.030)	(0.023)	(0.063)	(0.034)	(0.006)	(0.010)	(0.014)	(0.012)
Size squared	0.003	0.004**	0.036***	0.002	0.000	0.001	0.003	-0.001
	(0.003)	(0.002)	(0.013)	(0.003)	(0.000)	(0.001)	(0.002)	(0.001)
Industry level legal protection	0.037	0.133	0.037	0.082	0.009	-0.013	0.023	-0.023
	(0.144)	(0.172)	(0.192)	(0.118)	(0.038)	(0.027)	(0.039)	(0.026)
Public support	0.059***	0.038**	0.025**	0.030	0.011***	0.024***	0.017***	0.002
	(0.018)	(0.018)	(0.012)	(0.021)	(0.04)	(0.006)	(0.004)	(0.007)
Absolute basicness of R&D	0.196***	0.122***	0.196***	0.192***	0.016**	0.023**	0.035	0.013*
	(0.034)	(0.032)	(0.022)	(0.041)	(0.008)	(0.009)	(0.021)	(0.007)
Export intensity	0.077**	-0.071**	-0.008	-0.014	0.005	-0.005	-0.001	0.029***
	(0.030)	(0.035)	(0.023)	(0.027)	(0.005)	(0.012)	(0.010)	(0.010)
Industry level of cooperation	-0.249***	-0.017	-0.015	-0.057	-0.022	-0.015	-0.002	-0.023
	(0.084)	(0.108)	(0.076)	(0.107)	(0.016)	(0.018)	(0.032)	(0.018)
Industry level incoming spillovers	-0.006	0.061	-0.108	-0.142	-0.004	-0.018	-0.019	0.002
	(0.234)	(0.170)	(0.130)	(0.240)	(0.051)	(0.033)	(0.020)	(0.048)
Industry level appropriability	0.083	-0.041	-0.053	-0.081	0.008	0.005	-0.027	0.003
	(0.131)	(0.124)	(0.153)	(0.110)	(0.037)	(0.027)	(0.025)	(0.017)
Industry level R&D intensity	-0.053	-0.325	-0.115	0.123	0.993***	1.001***	0.970***	1.019***
	(0.197)	(0.240)	(0.122)	(0.341)	(0.139)	(0.280)	(0.099)	(0.231)
Industry level constraints	0.987***	0.840***	0.873***	0.863***	-0.004	-0.026	-0.028	-0.003
	(0.121)	(0.138)	(0.116)	(0.147)	(0.019)	(0.027)	(0.058)	(0.040)
Constant	-0.057	0.202*	0.381***	0.192	-0.011	0.042	0.049*	-0.004
	(0.100)	(0.114)	(0.094)	(0.135)	(0.020)	(0.027)	(0.026)	(0.039)
R^2	0.07	0.08	0.06	0.05	0.31	0.23	0.30	0.21
No. observations	3,590	1,183	2,747	1,145	3,590	1,183	2,747	1,145

***significant at 1% level, **significant at 5% level, *significant at 10% level. Standard errors in parentheses.

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CHAPTER 3. ORGANIZATIONAL INNOVATION AND PRODUCTIVITY GROWTH: ASSESSING THE IMPACT OF OUTSOURCING ON FIRM PERFORMANCE

3.1. Introduction

It is widely accepted that innovation is a primary source of productivity growth. Literature on this topic has focused on the impact of investment on knowledge and the role of technological innovations. Since Griliches (1979), many empirical studies have focused on the link between R&D and productivity[66] and on the role of technological process and product innovations as productivity shifters[67].

However, as it is pointed out in the Oslo Manual (OECD, 2005): "In order to identify the full range of changes that firms undertake to improve performance and their success in improving economic outcomes, a framework broader than technological product and process innovation is needed. Including marketing and organizational innovations gives a more complete framework that is better able to capture the changes that affect firm performance and contribute to the accumulation of knowledge".

Organizational innovations can have an important effect on productivity on their own. In this sense, organizational innovations can increase the quality and efficiency of work and improve the information sharing and the ability of the firm to use new technologies, as such increasing the productivity of investment in knowledge.

Broadly speaking, an organizational innovation is defined as the adoption of a new idea or behavior by an organization (see Daft, 1978). More precisely, and following the Oslo Manual (OECD, 2005) "organizational innovations refer to the implementation of new organisational

[66] See Griliches (1995) for a survey.

[67] Crépon et al. (1998) propose a structural model that describes the link between R&D expenditure, innovation output and productivity. This model, widely used, has been recently applied by Griffith et al. (2006) using internationally comparable firm-level data from four major European countries, France, Germany, Spain and the UK.

methods. These can be changes in business practices, in workplace organisation or in the firm's external relations".

In this chapter, I consider one of the most relevant organizational methods in firms' external relations, outsourcing. Outsourcing is a make or buy decision and implies the modification of the boundaries of the firm. It must be seen as part of the organizational innovation process, carried out in the search for increasing flexibility and efficiency.

There is no standardized definition of the term outsourcing. A general definition of outsourcing refers to those material inputs or services necessary to produce a final output obtained outside the firm. One strand of literature focuses on the outsourcing of materials. In this sense, McMillan (1995) enumerates the main changes introduced by U.S. firms in their supplier relationships. Among the most relevant changes is the increment in the contracting out of manufacturing activities or production subcontracting. Several papers analyze the evolution of material outsourcing. See, for example, Feenstra and Hanson (1996), Hummels et al. (2001), Yeats (2001), Hanson et al. (2004), and Borga and Zeile (2004). In another strand of literature, several papers address the substantial growth in service outsourcing. See, among others, Abraham and Taylor (1996), Goodman and Steadman (2002), Abramovsky et al. (2004) and Amiti and Wei (2005).

In addition, outsourcing can be local (an external supplier in the domestic market) or international (a leading example is the outsourcing by firms in developed countries to firms located in low-wage countries).

What is more, from an empirical perspective outsourcing is too broad a concept. In this sense, outsourcing has been measured in many different ways and using different perspectives. Most of the measures collect information at the industry level and from input-output tables, rather than firm-level data. Moreover, many of them are rough measures.

Among the most used measures of outsourcing is Feenstra and Hanson's (1996) approach[68]. These authors define outsourcing share for each industry as the share of imported intermediate inputs (services) over total non-energy inputs. Other measures of outsourcing used are, among others, imported intermediate inputs within each industry obtained from

[68] For example, see Feenstra and Hanson (1999), Amiti and Wei (2005, 2006), and Canals (2006a, 2006b).

input-output tables, expenditure on a number of specific services purchased on the market, fraction of the work in business services contracted out, material inputs relative to internal labour costs and external contract work.

The aim of this chapter is to analyze the relationship between a particular form of organizational innovation (outsourcing) and productivity. Specifically, this chapter deals with outsourcing at the firm level and focuses on the role of contracting out of manufacturing activities (production subcontracting). I adopt an econometric approach, i.e., I focus on the econometric estimation of production functions. In this sense, firstly, I introduce a simple framework that specifies a production function considering the possibility of production subcontracting. The framework developed leads to the estimation of a production function depending on traditional inputs (labour, capital and materials) and an index of production subcontracting. Specifically, both the effect of first-time outsourcing on productivity and the effect of the intensity of production subcontracting can be analyzed. This simple framework has shortcomings and the last section deals with them. In this sense, this section is a first attempt at modelling and estimating a more structural framework for the specification of a production function considering the possibility of production subcontracting. This framework allows to identify two labour "uses" (labour used "directly" in the production of the final output and labour used in the production of the intermediate input).

Estimation is carried out using an unbalanced panel survey of Spanish manufacturing firms. The main equation is estimated using a sample of 1,728 firms, observed during the period 1990-1999. This sample is representative of the manufacturing population of firms.

The contribution of this study to the empirical literature on the relationship between outsourcing and productivity is three-fold. First, I analyze both the effect of the decision to outsource and the effect of outsourcing intensity. In doing this, I develop a simple theoretical framework justifying the introduction of an outsourcing measure to the estimation of a "traditional" production function. Second, my analysis is performed at the firm level and uses panel data. Panel data allows us to account for unobserved heterogeneity and analyze temporal effects. Third, I use a "direct" measure for outsourcing of manufacturing activities. In this sense, I have information on firms' purchases of elaborated products and customized components from external suppliers. Outsourcing of intermediate inputs takes on greater importance when the products being exchanged are not raw materials, but have some degree of elaboration. In this case, it is plausible that outsourcing of manufacturing activities implies the externalization of stages of the production process (potentially increasing flexibility and efficiency). But this practice will also involve the costs of finding a suitable supplier and imperfect contracting.

In what follows, I present some related literature. I focus on two strands of empirical literature[69]: (i) Literature studying the effect of (the broad concept of) organizational innovation on productivity, and (ii) Literature focused on productivity effects of outsourcing. Although this revision does not aim to be comprehensive, I present the main trends in empirical literature and relevant findings.

Organizational innovation and productivity growth

There are an increasing number of studies that suggest a significant and positive effect of various measures of organizational innovation on productivity. At this point, I will focus on some relevant examples of this literature.

A strand of literature focuses on the effect of the adoption of alternative human resource management practices, such as flexible job definitions, training, work teams, and incentive pay[70]. Most of this studies find that the adoption of a coherent system of human resource management practices results in substantially higher levels of productivity than more traditional human resource management practices. Moreover, the existence of synergies among

[69] Regarding theoretical studies on outsourcing, the early literature treated the industry environment as given and has focused on the relation between a single producer and a potential supplier (see, among others, Kamien, Li and Samet, 1989; Lewis and Sappington, 1991; and Spiegel, 1993). Recently, Grossman and Helpman (2002) developed a model in which integration and outsourcing are treated as equilibrium phenomena (taking into account the interdependence among the firms' choices). These authors focus on the trade-off between the costs of running a larger and less specialized firm and the costs of search frictions and imperfect contracting. Subsequently, Grossman and Helpman (2003) develop a model in which firms in an industry choose their organization structures and the location of their suppliers, and Grossman and Helpman (2005) study the determinants of the location of subcontracted activity in a general equilibrium model of outsourcing and trade.

[70] See Ichniowski and Shaw (2003) for a recent review of this literature.

workplace practices is also found.

Black and Lynch (2001, 2004) also examine the impact of workplace practices on the productivity of firms. These authors define organizational innovation as including human resource management practices such as organizing workers in teams, job rotation, training for non-managerial workers, and re-engineering. They find for the manufacturing sector that implementing these organizational innovations in a unionized setting resulted in higher productivity than doing the same thing in a non-unionized setting. They also find that what is more important for productivity is the diffusion of a practice inside an organization rather than the simple adoption of the practice.

Most interesting, Black and Lynch (2004) use the estimates of the impact of organizational innovation on productivity in a growth accounting framework to see how much of the growth in output from 1993-1996 in US manufacturing might be accounted for by organizational practices. It appears that workplace practices and re-engineering efforts accounted for as much as 30 percent of output growth over this period of time.

Using firm level data from the U.S., Bresnahan et al. (2002) find that investments in certain specific types of work organization[71] are associated with high measured productivity. Moreover, these authors find that information technology, complementary workplace reorganization and human capital are positively correlated.

Gera and Gu (2004), using micro data from Canada, find that three organizational changes (the restructuring of production processes, human resource management practices and product/service quality-related practices) are positively related to productivity performance.

Finally, a large body of literature focuses on the "indirect" effect of organizational changes on firm performance through investment in information technology. In this sense, Brynjolfsson and Hitt (2000) review the evidence on how organizational innovations (such as new business processes, new skills or new organizational structures) are major drivers of the

[71] Variables measuring organization are related to team-based work organization (for example, use of self-managing teams, use of team-building activities) and individual decision authority (who decides the pace of work and who decides the method of work).

contribution of information technology to productivity.

Outsourcing and productivity growth

Although it has not received much attention, outsourcing and its productivity effect is a growing research topic. Heshmati (2003) and Olsen (2006) present detailed surveys of recent contributions to the relationship between outsourcing and productivity growth in manufacturing and services.

Therefore, at this point, and given the existence of these surveys, I just stress the main issues and findings in this literature. First, the empirical literature has traditionally focused on productivity effects at the industry and country levels (see, among others, Baumol (1967), Siegel and Griliches (1992), Feenstra and Hanson (1996), Fixler and Siegel (1999), Ten Raa and Wolff (2001), Amiti and Wei (2006)). Evidence on the relationship between outsourcing and productivity growth is not conclusive. For example, Siegel and Griliches (1992), in assessing whether outsourcing leads to an overstatement of manufacturing productivity growth, find a weak correlation in the use of selected purchased services during the 1980s. Meanwhile, Ten Raa and Wolff (2001) find a positive association between the rate of outsourcing and productivity growth in the goods sector. And Amiti and Wei (2006) find that both service outsourcing and material outsourcing have a positive and significant effect on productivity in the U.S. and that the effect of service outsourcing is greater in magnitude.

Second, some of the earliest papers estimating the relationship between outsourcing and productivity use firm-level data. Using a panel data of German manufacturing firms, Görzig and Stephan (2002) estimate the effect of three measures of outsourcing on firm performance (measured by both the returns per employee and the returns on sales). The three measures of outsourcing are: (i) material inputs relative to internal labour costs, (ii) external contract work relative to internal labour costs, and (iii) other costs not related to production relative to internal labour costs. These authors find a positive and significant effect of all three measures of outsourcing on returns per employee, and a negative effect on returns on sales.

Another example of firm-level evidence is Girma and Görg (2004). These authors use manufacturing establishment level data for the U.K. and define outsourcing as the cost of industrial services[72] received by an establishment. They find that an establishment's outsourcing intensity is positively related to its labour productivity and total factor productivity growth.

Thirdly, existing empirical literature on outsourcing deals in good part with other topics. Many papers focus on labour market issues (see, among others, Feenstra and Hanson (1995, 1996, 1999), Estevao and Lach (1999), Anderton and Brenton (1999), Falk and Koebel (2000)), while another strand of literature analyzes the determinants of outsourcing. For example, Abraham and Taylor (1996) report empirical findings of employers' motives for contracting out business services in U.S. industry. These authors find empirical evidence supporting the influence of wage savings, economies of scale and smoothening production cycles on the decision to outsource.

The rest of the chapter is organized as follows. Section 3.2 introduces the theoretical framework. Section 3.3 details the econometric equation to be estimated. Section 3.4 introduces the data set and the variables, and describes the main facts about production subcontracting for Spanish manufacturing firms during the 1990s. Section 3.5 presents the empirical results. Section 3.6 is a first attempt at modelling and estimating a more structural framework. Finally, Section 3.7 concludes.

3.2. Theoretical framework

This section is aimed at introducing a simple framework to be used when specifying a production function considering the possibility of production subcontracting. As I said before, I start from the econometric estimation of a production function, and I need some theoretical background to justify the changes in the "traditional" production function due to the introduction of variables measuring outsourcing.

For simplicity, I assume that firm j produces a single output Y at time t with a Cobb-Douglas production function with constant returns to scale:

[72] These industrial services includes activities such as processing of inputs which are then sent back to the establishment for final assembly or sales, maintenance of production machinery, and engineering or drafting services.

$$Y_{jt} = A_{jt} K_{jt}^{\delta} L_{jt}^{\alpha} I_{jt}^{1-\alpha-\delta} \tag{3.1}$$

Dropping firm and time subscripts for simplicity, A is an index of Hicks-neutral technical progress. K represents the capital stock and L the labour input. Given technology, it is necessary to use an input I. This input can be produced within the firm (I_f) or can be purchased (I_s).

Input I can also be obtained combining in-house production and outside sources. To control for substitution between I_f and I_s, I express the procurement of I as follows:

$$I = I_s^{\lambda} I_f^{1-\lambda} \tag{3.2}$$

Parameter λ determines the substitutability between in-house production and production subcontracting of the intermediate input I.

Finally, production within the firm of input I can be written as:

$$I_f = L^{\gamma} M^{1-\gamma} \tag{3.3}$$

where L represents labour input and M row materials plus external services (intermediate consumptions excluding subcontracted purchases). For simplicity, the capital input (K) is not included in the internal production of I.

Given equation (3.2) I can write that:

$$I = I_f \left(\frac{sr}{1 - sr} \right)^{\lambda} \tag{3.4}$$

where $sr = \frac{I_s}{I_f + I_s}$. The variable sr represents the proportion of intermediate input I that is subcontracted. Therefore, ratio $\frac{sr}{1-sr}$ is an index of production subcontracting. The higher sr is, the higher $\frac{sr}{1-sr}$ is, and hence the higher the intensity of production subcontracting is. This index is one measure of the "relative" importance of production subcontracting ("relative" in the sense that it is not a direct measure of subcontracted purchases. It is a measure of the importance of subcontracted purchases with respect to total intermediate consumptions).

Given (3.2) and (3.4) I can write

$$I = \begin{cases} I_f, \text{ if there is no outsourcing} \\ I_f \left(\frac{sr}{1-sr}\right)^{\lambda}, \text{ if there is outsourcing} \end{cases} \tag{3.5}$$

Substituting (3.3) and (3.5) in (3.1), I can write:

$$Y = \begin{cases} AK^{\delta}L^{\phi_1}M^{\phi_2}, \text{ if there is no outsourcing} \\ AK^{\delta}L^{\phi_1}M^{\phi_2}\left(\frac{sr}{1-sr}\right)^{\phi_3}, \text{ if there is outsourcing} \end{cases} \tag{3.6}$$

where $\phi_1 = \alpha + \gamma(1-\alpha-\delta)$, $\phi_2 = (1-\gamma)(1-\alpha-\delta)$ and $\phi_3 = \lambda(1-\alpha-\delta)$. Show that $\delta + \phi_1 + \phi_2 + \phi_3 = 1 + \phi_3$. And hence $\delta + \phi_1 + \phi_2 = 1$. This constraint implies constant returns to scale in the conventional inputs (K, L, M).

Note that the term $\left(\frac{sr}{1-sr}\right)^{\phi_3}$ is the only difference between the specification of a production function with and without production subcontracting.

3.3. Econometric model

Taking logarithms in expression (3.6), I can write:

$$\log Y = \begin{cases} \log A + \delta \log K + \phi_1 \log L + \phi_2 \log M, \text{ if there is no outsourcing} \\ \log A + \delta \log K + \phi_1 \log L + \phi_2 \log M + \phi_3 \log\left(\frac{sr}{1-sr}\right), \text{ if there is outsourcing} \end{cases} \tag{3.7}$$

To estimate a production function for firms with and without production subcontracting simultaneously, I write the production function adding a dummy variable indicating non-outsourcing. Now, I can write:

$$\log Y = \log A + \delta \log K + \phi_1 \log L + \phi_2 \log M + \phi_3 \log SUB + \beta subdum \tag{3.8}$$

where:

$$\log SUB = \begin{cases} 0, \text{ if there is no outsourcing} \\ \log \frac{sr}{1-sr}, \text{ if there is outsourcing} \end{cases} \tag{3.9}$$

$$subdum = \begin{cases} 1, \text{ if there is no outsourcing} \\ 0, \text{ if there is outsourcing} \end{cases} \tag{3.10}$$

I carry out all estimates in differences. Therefore, variables are in log differences. The specification in log differences or rates of growth implies that any level time-invariant individual or heterogeneous effects are differenced out. Taking differences in expression (3.8), two caveats should be noted:

1. $\log SUB$ is not a continuous variable. And hence, the rate of growth (i.e., log differences) corresponding to a change in the outsourcing decision is not defined.

2. Differences of variable subdum (ddums) takes the values:

$$\text{ddums}=\begin{cases} 1\text{, if the firm stops outsourcing (with respect to the previous period)} \\ 0\text{, period without change in the outsourcing decision} \\ -1\text{, if the firm starts outsourcing (with respect to the previous period)} \end{cases} \tag{3.11}$$

Solving these problems, firstly, a rate of growth for $\frac{sr}{1-sr}$ equal to zero is assigned to those observations corresponding to periods with changes in the outsourcing decision.

$$sub=\begin{cases} \log\left(\frac{sr}{1-sr}\right)_t - \log\left(\frac{sr}{1-sr}\right)_{t-1}, \text{ if there is outsourcing at } t \text{ and at } t-1 \\ 0\text{, otherwise} \end{cases} \tag{3.12}$$

Secondly, to identify changes in the outsourcing decision, two dummy variables (substop, substart) are considered:

$$substop=\begin{cases} 1\text{ , if ddums=1} \\ 0\text{, otherwise} \end{cases} \tag{3.13}$$

$$substart=\begin{cases} 1\text{ , if ddums}=-1 \\ 0\text{, otherwise} \end{cases} \tag{3.14}$$

The relevant equation to be estimated may be expressed as follows:

$$\widetilde{y} = a + \delta\widetilde{k} + \phi_1\widetilde{l} + \phi_2\widetilde{m} + \phi_3 sub + \beta_1 substop + \beta_2 substart + \varphi cu + D\rho + \widetilde{v} \tag{3.15}$$

where $\widetilde{y}$, $\widetilde{k}$, $\widetilde{l}$ and $\widetilde{m}$ are, respectively, the rates of growth or log differences of output, capital, labour and intermediate consumptions (excluding subcontracted purchases). The variable *sub* is the rate of growth of the index of production subcontracting (see expression (3.12)).

Equations in levels are assumed to present an error term (u) that can be decomposed as $u_{it} = \mu_i + v_{it}$, where μ_i is the time-invariant term that accounts for the heterogeneity across firms. As I said before, the specification in first differences implies that the term μ_i is eliminated from the residual. The term v is assumed to be an uncorrelated zero mean error term, and $\widetilde{v}_{it} = v_{it} - v_{it-1}$.

The estimation of a production function makes it important to control for input utilization, and hence the inclusion of the capacity utilization variable (cu). D represents the set of dummy variables included. Theoretical constraint $\delta + \phi_1 + \phi_2 = 1$ can either be tested or imposed on the estimation in order to gain efficiency.

To summarize, expression (3.15) is the relevant equation to be estimated. In addition to traditional "inputs", an index of outsourcing intensity and a couple of dummy variables representing changes in the outsourcing decision are taken into account. Since this study is aimed at analyzing the relationship between outsourcing and productivity, I am interested in estimating parameters δ, ϕ_1, ϕ_2, ϕ_3, β_1 and β_2. The estimation of other parameters of the model (i.e., α, λ and γ) exceeds the purpose of this section. Briefly, I cannot estimate these parameters because I do not distinguish between labour used in the production of Y and the labour used in the production of I_f (note that L in expression (3.8) measures the total amount of labor used by the firm). In Section 3.6 I deal with this issue.

3.4. Data, variables and description

I present estimates based on an unbalanced sample of 1,728 Spanish manufacturing firms during the period 1990-1999. The data used correspond to the official survey "Encuesta sobre Estrategias Empresariales", ESEE, (Survey on Firm Strategies). ESEE is an unbalanced panel survey of Spanish manufacturing firms with 10 or more workers, starting in 1990 and sponsored by the Ministry of Industry. At the beginning of the survey, all firms with more than 200 workers were requested to participate, while a representative sample of 5% of the firms with fewer than 200 workers was randomly selected. The final sample employed depends on the data available and the number of consecutive time observations required. Table 3.A1 (see Appendix 3.C) shows the composition in terms of time observations of the unbalanced panel sample used. The sample employed to estimate equation (3.15) consists of all the firms that have been surveyed for at least three consecutive years after dropping all the time observations for which the data needed are not available.

ESEE provides detailed information on firms' output, capital, labour (measured through total hours of work) and intermediate consumptions. Moreover, the data provide information about the outsourcing of manufacturing activities (production subcontracting). Specifically, I have information indicating whether the firm subcontracts production and information about subcontracted purchases (firms' purchases of elaborated products and customized components to external suppliers.). This information allows me to define the ratio between subcontracted purchases and (total) intermediate consumptions (which will be used as a proxy for the theoretical variable sr). Hence, the theoretical index of production subcontracting, $\left(\frac{sr}{1-sr}\right)$, can be constructed.

A unique feature of this data set is the availability of information on the changes in the prices set by the firm, and on the changes in the prices that the firm pays for its non-labour inputs. Detailed definitions of all employed variables can be found in Appendix 3.A. Moreover, Table 3.A2 (see Appendix 3.C) gives some descriptive statistics of the key variables.

In what follows, I present the main facts regarding production subcontracting for Spanish manufacturing firms during the 1990s[73]. I analyze it along two dimensions: the percentage of firms that contract out manufacturing activities (Tables 3.1 and 3.2), and outsourcing intensity among performers (Tables 3.3 and 3.4).

Table 3.1 shows the percentage of firms contracting out manufacturing activities during the period 1990-99. Big firms are more likely to subcontract, and this gap does not decrease during the period. Moreover, it seems that there is a positive relationship between the decision of production subcontracting and the Spanish industrial cycle during the 1990s. The period analyzed coincides with a complete industrial cycle. In 1991, manufacturing

[73] See López (2002) for a more detailed description of production subcontracting and externalization of services by Spanish manufacturing firms during the 1990s.

Table 3.1. Percentage of firms contracting out of manufacturing activities

Total manufacturing (by year)

	All firms	Up to 200 workers	More than 200 workers
1990	39.9	31.7	53.1
1991	50.6	42.9	65.3
1992	46.2	41.8	55.9
1993	44.0	39.2	55.9
1994	41.9	36.6	54.6
1995	42.6	37.3	54.8
1996	42.6	37.2	55.0
1997	45.6	41.1	55.8
1998	47.5	42.7	58.3
1999	43.7	36.9	58.8
Total[1]	44.7	39.9	55.6

[1]Average of period 1990-99

experienced an important downturn. Recovery started in 1994 with only a minor halt in 1996 and in 1999. The percentage of firms contracting out manufacturing activities reflects a similar evolution (see Figure 3.1).

Regarding differences between industries[74], Table 3.2 shows that firms from Ind. and agric. machinery (industry 4), Office mach. and elec. goods (industry 5), Transport equipment (industry 6), and Other manufacturing products (industry 11) are highly active in outsourcing.

Four industries are in an intermediate position: Metals and metal products (industry 1), Chemical products (industry 3), Textile, leather and shoes (industry 8), and Paper and printing products (industry 10).

Three industries -Non-metallic minerals (industry 2), Food, drink and tobacco (industry 7), and Timber and furniture (industry 9)- exhibit lower percentages.

[74]I consider 11 industries. Industry breakdown is defined in Appendix 3.B.

Figure 3.1. Percentage of firms contracting out of manufacturing activities

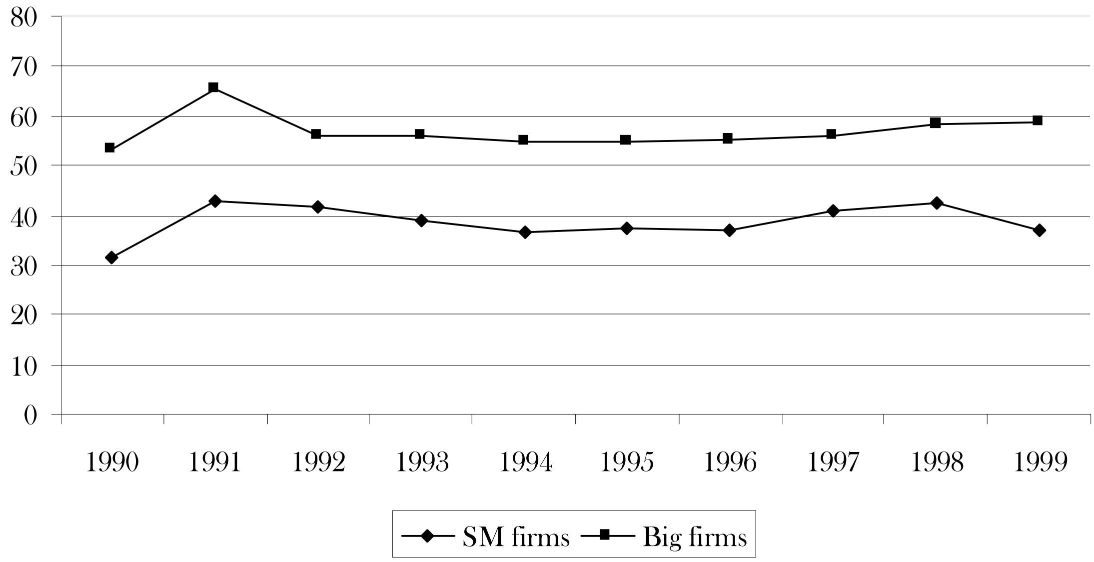


Figure 3.2. Subcontracted purchases over Intermediate consumptions

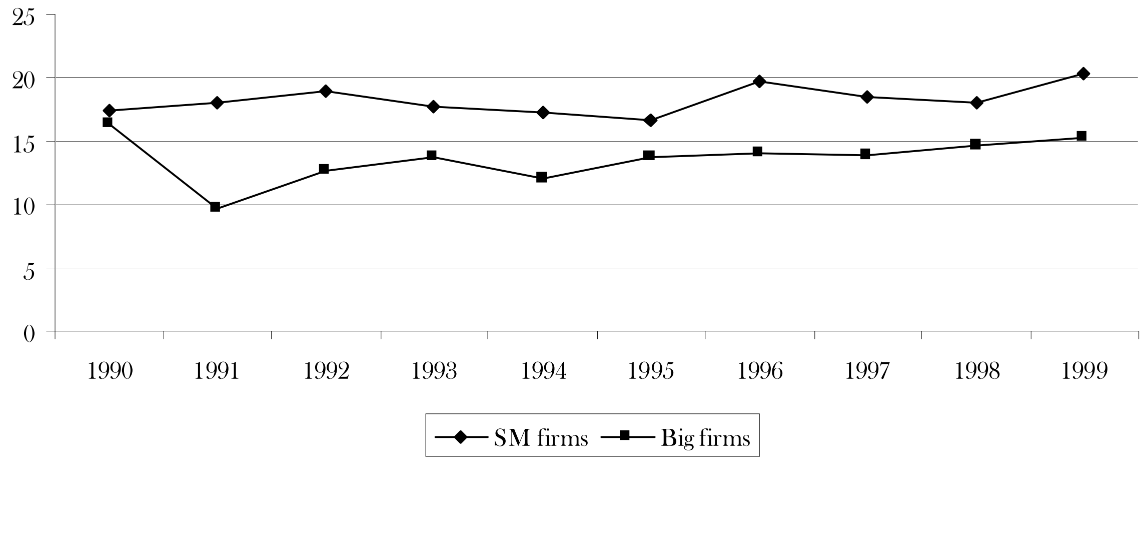


Table 3.2. Percentage of firms contracting out of manufacturing activities[1]

Total manufacturing (by industry)

	All firms	Up to 200 workers	More than 200 workers
1. Metals and metal products	47.0	46.3	48.5
2. Non-metallic minerals	26.5	24.1	36.5
3. Chemical products	43.6	35.3	59.3
4. Ind. and agric. machinery	65.4	65.2	64.1
5. Office mach. and elec. goods	61.5	55.2	66.1
6. Transport equipment	59.9	50.4	63.1
7. Food, drink and tobacco	21.5	13.4	39.8
8. Textile, leather and shoes	50.4	47.4	62.6
9. Timber and furniture	33.0	33.0	45.0
10. Paper and printing products	53.9	51.7	61.0
11. Other manufacturing products	63.6	62.7	77.4
Total manufacturing	44.7	39.9	55.6

[1]Average of period 1990-99

To analyze the outsourcing intensity, I use the ratio between subcontracted purchases (a firm's purchases of elaborated products and customized components) and (total) intermediate consumptions. I restrict my attention to those firms active in outsourcing. This ratio is 18.0% for firms with than 200 workers and 14.0% for firms with more than 200 workers (see Table 3.3). I find out that small firms are more intensive in production subcontracting than big ones. This result may be shown in the bidirectional relation between outsourcing and the firm's structure, specifically between outsourcing and firm size (measured by the number of workers). The higher the intensity in subcontracting is, the higher the substitution of intermediate consumptions for labour is.

Figure 3.2 shows the evolution of the ratio between subcontracted purchases and intermediate consumptions over time. In this case, there is not a straight relationship between the intensity of production subcontracting and the industrial cycle. Moreover, there appears to

Table 3.3. Subcontracted purchases[1] over Intermediate consumptions (%)

Firms contracting out of manufacturing activities (by year)

	All firms	Up to 200 workers	More than 200 workers
1990	16.9	17.4	16.4
1991	14.4	18.0	9.7
1992	16.6	19.0	12.6
1993	16.3	17.8	13.7
1994	15.3	17.3	12.0
1995	15.6	16.7	13.7
1996	17.5	19.8	14.0
1997	16.8	18.5	13.9
1998	16.7	18.0	14.6
1999	18.2	20.3	15.3
Total[2]	16.5	18.0	14.0

[1]Firm's purchases of elaborated products and customized components

[2]Average of period 1990-99

be differences between small-medium firms and big firms.[75]

Table 3.4 shows intensity in production subcontracting by industry. There are differences between the share of firms active in outsourcing and outsourcing intensity. In this sense, the industries with the highest outsourcing intensity are: Ind. and agric. machinery (industry 4), Transport equipment (industry 6), Textile, leather and shoes (industry 8), Timber and furniture (industry 9) and Paper and printing products (industry 10). Industry 9, however, exhibits a low percentage of firms active in outsourcing.

Three industries are in an intermediate position: Metals and metal products (industry 1), Office mach. and elec. goods (industry 5) and Other manufacturing products (industry 11), and three industries -Non-metallic minerals (industry 2), Chemical products (industry

[75]See Delgado et al. (1999), and López (2002) for evidence on the relationship between outsourcing and the Spanish industrial cycle during the 1990s.

Table 3.4. Subcontracted purchases[1] over Intermediate consumptions[2] (%)

Firms contracting out of manufacturing activities (by industry)

	All firms	Up to 200 workers	More than 200 workers
1. Metals and metal products	15.3	16.7	13.0
2. Non-metallic minerals	11.6	12.7	10.1
3. Chemical products	9.8	10.4	9.7
4. Ind. and agric. machinery	22.3	23.7	18.4
5. Office mach. and elec. goods	17.1	18.1	15.7
6. Transport equipment	19.8	21.4	18.8
7. Food, drink and tobacco	10.5	12.4	9.9
8. Textile, leather and shoes	18.7	19.5	15.5
9. Timber and furniture	19.8	20.0	15.9
10. Paper and printing products	21.5	24.2	13.2
11. Other manufacturing products	14.0	12.5	18.7
Total manufacturing	16.5	18.0	14.0

[1]Firm's purchases of elaborated products and customized components

[2]Average of period 1990-99

3), and Timber and furniture (industry 9)- exhibit lower outsourcing intensities.

3.5. Empirical results

Equation (3.15) is a linear equation with predetermined and endogenous variables. GMM techniques[76] are applied for their estimation. The instruments used in each estimate are detailed in the notes to the tables. Sargan tests of the overidentifying restrictions are reported for each estimate.

Each estimate includes m_1 and m_2 Arellano and Bond (1991) test statistics for first and second-order serial correlation[77]. As I said before, equations in levels are supposed to present

[76]See Arellano and Honoré (2002) for a recent review of this method.

[77]m_1 and m_2 test statistics are asymptotically distributed as a $N(0,1)$ under the null hypothesis of no

an uncorrelated zero mean disturbance, and hence, disturbances of the differenced equation are expected to show a significant negative first-order autocorrelation, but an absence of correlation of higher orders.

Estimation of the production function is carried out taking capital as predetermined, and labour, non-subcontracted intermediate consumptions and subcontracted purchases as endogenous variables.

Equations include eighteen industry dummies and yearly time dummies. These industry and time dummies are included with their coefficients constrained to add up to zero (Suits method). I include a dummy indicating whether the firm was created during the period, and one dummy indicating whether the firm is going to exit during the period. Moreover, to control for discrete changes, dummies indicating merger/acquisition or scission are included.

3.5.1. Manufacturing level results

Table 3.5 presents the results for the estimation of equation (3.15) for manufacturing as a whole. Estimate *a* presents OLS results, while estimates *b*, *c* and *d* take into account the endogeneity of input choices and present GMM results. The preferred outcome is estimate *d*. Estimates *b* and *c* are used to check their robustness.

On the one hand, constant returns to scale in the conventional inputs -capital, labour and intermediate consumptions (excluding subcontracted purchases)- are accepted (see the Wald test for this restriction in estimate *b*). Estimates *c* and *d* impose this constraint. On the other hand, inclusion of capacity utilization does not change the coefficients of the other variables, but it is an important variable for explaining production shifts and it improves the result concerning second-order serial correlation (compare estimates *c* and *d*). The Sargan test allows me to accept the set of instruments employed.

Estimated elasticities for traditional inputs show plausible values. Low and insignificant capital coefficient in estimate *b* is consistent with traditional findings using GMM tech-

autocorrelation.

Table 3.5. Production function estimates

Equation: $\widetilde{y} = \alpha + \delta\widetilde{k} + \phi_1\widetilde{l} + \phi_2\widetilde{m} + \phi_3 sub + \beta_1 substop + \beta_2 substart + \widetilde{v}$				
Sample period: 1992-1999				
N^o of firms: 1728				
Dependent variable: $\widetilde{y}$				
Independent variables[2]	a (OLS)	b (GMM[1])	c (GMM[1])	d (GMM[1])
Constant	0.03(9.7)	0.02(2.0)	0.02(2.4)	0.02(2.2)
$\widetilde{k}$	0.05(4.9)	0.13(1.38)	0.13	0.15
$\widetilde{l}$	0.29(10.9)	0.36(3.8)	0.37(4.0)	0.36(3.8)
$\widetilde{m}$	0.40(16.4)	0.49(7.2)	0.50(8.0)	0.49(8.0)
sub	0.07(10.7)	0.14(4.5)	0.14(4.7)	0.14(4.6)
$substop$	−0.07(−7.9)	−0.08(−7.2)	−0.08(−7.3)	−0.08(−7.4)
$substart$	0.06(6.5)	0.07(5.2)	0.07(5.4)	0.07(5.4)
cu	0.10(4.9)	0.06(2.5)	–	0.06(2.6)
Industry dummies[3]	Included	Included	Included	Included
Time dummies[3]	Included	Included	Included	Included
m_1	–	−9.0	−9.2	−9.3
m_2	–	−1.5	−1.67	−1.5
Sargan test (df)	–	21.7(22)	21.6(23)	21.6(23)
Wald test (df)	–	0.02(1)	–	–

Heteroskedasticity robust t-ratios shown in parentheses.

[1]Instruments are: l, m and sub-lagged levels t-2; lagged log-differences of k; and one size dummy (>200 workers).

[2]Wald test allows us to accept $\delta + \phi_1 + \phi_2 = 1$. Estimates c and d impose this constraint.

[3]18 industry dummies (ESEE Industries) and 8 year dummies, with the coefficients of each set constrained to add up to zero; dummies for entering and exiting firms, as well as mergers and scissions, also included.

niques[78].

As expected, the index of production subcontracting, $\left(\frac{sr}{1-sr}\right)$, appears to be significantly associated with productivity. All estimates show that intensity of outsourcing has a positive and significant effect on total factor productivity. In other words, keeping the "traditional" factors of production constant, increasing the share of production subcontracting (measured as firms' purchases of elaborated products and customized components over total intermediate consumptions) leads to higher output.

It is not only the intensity that has a positive effect on production, but also the subcontracting decision. The coefficient of the *substart* variable is positive and significant, saying that the decision to start production subcontracting has a positive effect on production. The *substop* variable goes the other way around. Moreover, these results are robust to the use of a different set of instruments (see Table 3.A3 in Appendix 3.C).

Therefore, I find evidence supporting the importance of production subcontracting as a production shifter. This practice (viewed as an organizational innovation) increases flexibility and efficiency, having its final effect on firm-level productivity.

3.5.2. Results by industry

Production behavior and technology are very likely to vary across industries. Table 3.6 presents the results of estimating equation (3.15) using GMM techniques and under the assumption of constant returns to scale for each industry. The industry breakdown considered is defined in Appendix 3.B. I exclude industry 11 because of a lack of observations (only 35 firms belong to this industry. See Table 3.A1 in Appendix 3.C for further details).

Before discussing the main industry level results, Table 3.7 reports specification tests to check the validity of the estimates by industry. First, constant returns to scale in the conventional inputs are accepted by a wide margin for industries 2, 4, 5, 6, 8 and 9. Constant returns to scale are accepted for industries 1, 3 and 7 with a little ground for concern.

[78] See Blundell and Bond (2000), and Griliches and Mairesse (1998) for a discussion about this problem. See García, Jaumandreu and Rodríguez (2002) for a similar result on capital coefficient using ESEE.

Second, I test for overidentifying restrictions or validity of the moment conditions. The Sargan test very clearly indicates the validity of the moment conditions.

Industry level results indicate (see Table 3.6) that industry differences in the estimated factor elasticities are quite sizeable. Estimated elasticities of output with respect to labour go from 0.17 (industry 7. Food, drink and tobacco) to 0.66 (industry 8. Textile, leather and shoes), while materials elasticity estimates are spread over a narrower range, and go from 0.26 (industry 5. Office mach. and elec. goods) to 0.52 (industry 7. Food, drink and tobacco).

Regarding outsourcing variables, firstly, outsourcing intensity appears to be significantly associated with productivity for five industries (industry 1. Metals and metal products; industry 5. Office mach. and elec. goods; industry 7. Food, drink and tobacco; industry 9. Timber and furniture; and industry 10. Paper and printing products). Significant estimated coefficients of the *sub* variable are quite similar, and go from 0.08 to 0.14. Moreover, outsourcing intensity has a positive effect on productivity, mainly for firms belonging to light industries (industries 5, 7, 9 and 10).

This finding is not surprising since light industries are labour-intensive. For these industries, outsourcing intensity (substitution of intermediate consumptions for labour) has a greater effect on productivity growth (increasing flexibility and efficiency).

Secondly, dummy variables related to outsourcing decisions (*substop* and *substart*) are, in most of the cases, significant and have the expected effect on productivity. These variables have the greatest effect in Industry 6. Transport equipment. In this case, the negative effect of the decision to stop outsourcing is particularly important.

Table 3.6. Production function estimates. Results by industry

Equation: $\widetilde{y} = \alpha + \delta\widetilde{k} + \phi_1\widetilde{l} + \phi_2\widetilde{m} + \phi_3 sub + \beta_1 substop + \beta_2 substart + \widetilde{v}$

Sample period: 1992-1999

Estimation method: GMM[1]

Dependent variable: $\widetilde{y}$

Industry[2]	$\widetilde{k}$	$\widetilde{l}$	$\widetilde{m}$	*sub*	*substop*	*substart*
1. Metals and metal products	0.35	0.24(1.6)	0.41(3.2)	0.12(2.2)	−0.09(−2.5)	0.06(1.6)
2. Non-metallic minerals	0.20	0.46(2.6)	0.34(2.6)	0.006(0.1)	−0.05(−1.8)	−0.01(−0.5)
3. Chemical products	0.29	0.40(2.0)	0.31(1.9)	−0.03(−0.6)	−0.05(−2.3)	0.04(1.7)
4. Ind. and agric. machinery	0.13	0.53(3.1)	0.34(3.7)	0.02(0.9)	−0.08(−2.2)	0.07(2.2)
5. Office mach. and elec. goods	0.21	0.53(3.4)	0.26(2.1)	0.08(2.2)	−0.03(−0.7)	0.006(0.15)
6. Transport equipment	0.09	0.50(2.8)	0.41(2.6)	0.02(0.5)	−0.17(−3.7)	0.11(2.0)
7. Food, drink and tobacco	0.31	0.17(1.4)	0.52(5.3)	0.14(1.9)	−0.07(−3.6)	0.03(2.0)
8. Textile, leather and shoes	0.02	0.66(4.1)	0.32(2.4)	0.02(0.5)	−0.05(−1.8)	0.07(2.1)
9. Timber and furniture	0.26	0.37(2.2)	0.37(2.9)	0.12(1.9)	−0.05(−1.7)	−0.005(−0.07)
10. Paper and printing products	0.20	0.30(2.1)	0.50(4.3)	0.14(2.2)	−0.10(−2.9)	0.10(2.9)

Heteroskedasticity robust t-ratios shown in parentheses.

[1]Instruments are: l, m and sub-lagged levels t-2; lagged log-differences of k; and one size dummy (>200 workers). The set of instruments for industry 3 does not include the size dummy.

[2]Estimates include 8 year dummies, with the coefficients of each set constrained to add up to zero .Dummies for entering and exiting firms, as well as mergers and scissions, also included. The estimate for industry 3 also includes one size dummy (>200 workers). The estimate for industry 8 does not include dummies for entering firm, exiting firm, merger and scission.

Table 3.7. Specification tests. Results by industry

	Serial correlation		Constant returns to scale	Overidentifying restrictions
Industry	m_1	m_2	Wald test (df)	Sargan test (df)
1. Metals and metal products	−3.0	−0.6	7.1(1)	21.3(23)
2. Non-metallic minerals	−3.7	−1.1	2.2(1)	21.8(23)
3. Chemical products	−2.9	−1.4	7.7(1)	20.5(22)
4. Ind. and agric. machinery	−3.4	0.4	0.4(1)	22.3(23)
5. Office mach. and elec. goods	−2.4	−0.9	0.1(1)	19.0(23)
6. Transport equipment	−2.6	−0.9	1.3(1)	22.1(23)
7. Food, drink and tobacco	−3.6	0.2	5.7(1)	20.9(23)
8. Textile, leather and shoes	−2.8	−0.06	0.4(1)	24.6(23)
9. Timber and furniture	−2.1	−0.8	1.1(1)	15.6(23)
10. Paper and printing products	−2.8	−0.5	2.4(1)	22.6(23)

3.6. Estimating production functions when there is outsourcing

As I said in the introduction to this chapter, outsourcing is a make or buy decision. In this sense, the "buy" decision implies that a firm is purchasing an intermediate input with a certain degree of elaboration. Outsourcing implies that firms have access to intermediate inputs with different degrees of elaboration. The degree of elaboration is related to the quality of the intermediate input: the higher the degree of elaboration is, the higher the quality is[79].

In spite of its importance, outsourcing is not taken into account in the estimation of production functions. In this sense, intermediate inputs enter the production function without taking into account differences in the degree of elaboration (without taking into account quality differentials). Quality differences in the measures of inputs are important. Since the seminal paper by Griliches (1957), a key idea in the literature has been that productivity dispersion across firms may arise because firms use inputs with different qualities.

As pointed out by Griliches (1957), a kind of specification error occurs when inputs are measured without taking into account quality differentials. This author focuses on the effects of the disregard of quality differences in the measure of labour input, but argues that the same analysis can also be applied to the problem of disregarding the quality of other inputs.

This section is aimed at modelling and estimating a more structural framework than the model introduced in Section 3.2. It is based on two related ideas: (i) Outsourcing is a make or buy decision; and (ii) There are intermediate inputs with different degrees of elaboration. As I said in Section 3.3, this framework allows me to estimate all the parameters of interest of the model.

[79] Note that I am only considering the quality related with the degree of elaboration. Of course, there can be quality differentials across intermediate inputs with the same degree of elaboration. However, the data that I have does not allow me to control for this kind of quality differentials.

3.6.1. Theoretical model

Specification of production technology

Similar to expression (3.1), assume that firm j produces a single output Y at time t with a Cobb-Douglas production function with constant returns to scale:

$$Y_{jt} = A_{jt} K_{jt}^{\delta} L_{p,jt}^{\alpha} I_{jt}^{1-\alpha-\delta} \tag{3.16}$$

Dropping firm and time subscripts for simplicity, as in expression (3.1), A represents an index of Hicks-neutral productivity shift parameter, K the capital input, L_p the labour input used "directly" in the production of the final output, and I an intermediate input. Obtaining the intermediate input I, a firm can choose between inputs with different degrees of elaboration.

To consider the possibility of outsourcing, I take into account two basic features of this practice: (i) Outsourcing is a make or buy decision. In this sense, as in Section 3.2, I assume that a firm can opt to produce I within the firm, say I_f, but a firm can also combine in-house production of I with outside sources; and (ii) Intermediate input I contains inputs with different degrees of elaboration.

Given these special characteristics of outsourcing, I assume that the procurement of intermediate input I can be expressed as follows:

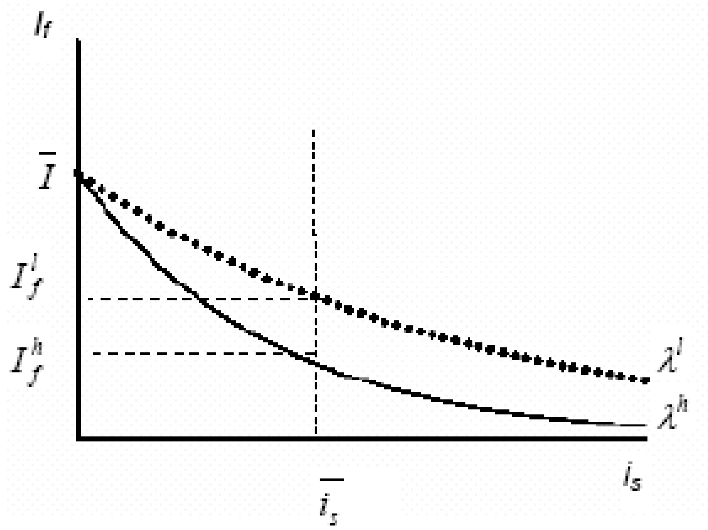
$$I = I_f e^{\lambda i_s} \tag{3.17}$$

To measure the degree of elaboration of I, I introduce an indicator of the importance of outsourcing in a firm (variable i_s). In this sense, the higher i_s is, the higher the importance of outsourcing is (i.e., the higher the degree of elaboration of the intermediate input is). This specification allows us to consider firms with outsourcing ($i_s > 0$) and without outsourcing ($i_s = 0$) simultaneously.

Note that $e^{\lambda i_s}$ is an efficiency term that indicates how much input I can be obtained by in-house production according to the degree of outsourcing. In other words, holding i_s

and I fixed ($\bar{i}_s$ and $\overline{I}$, respectively), the higher λ is, the lower in-house production (I_f) is necessary to achieve $\overline{I}$ (see Figure 3.3, where $\lambda^h > \lambda^l$).

Figure 3.3. Combining in-house production and outsourcing. $I = I_f e^{\lambda i_s}$



Finally, as in Section 3.2, production within the firm of input I can be written as:

$$I_f = L_f^{\gamma} M^{1-\gamma} \tag{3.18}$$

where M indicates the quantity of intermediate input measured without taking into account quality differentials. L_f represents labour input used in the production of I_f. For simplicity, capital input is not included in the production of I_f.

From (3.17) and (3.18) I can write:

$$I = L_f^{\gamma} M^{1-\gamma} e^{\lambda i_s} \tag{3.19}$$

Rewriting the production function

The production of I_f responds to the following cost minimization problem:

$$\begin{cases} Min\ wL_f + p_M^0 M \\ s.t.\ L_f^{\gamma} M^{1-\gamma} = \overline{I}_f \end{cases} \tag{3.20}$$

where p_M^0 is the price of M. Note that this price does not incorporate information on the degree of elaboration (i.e., it is the price without possible quality improvements). This price is not observable.

Solving (3.20), I get the conditional factor demand functions of L_f and M:

$$L_f(w, p_M^0, I_f) = I_f \left(\frac{w}{\gamma}\right)^{\gamma-1} \left(\frac{p_M^0}{1-\gamma}\right)^{1-\gamma} \tag{3.21}$$

$$M(w, p_M^0, I_f) = I_f \left(\frac{w}{\gamma}\right)^{\gamma} \left(\frac{p_M^0}{1-\gamma}\right)^{-\gamma} \tag{3.22}$$

From (3.21) and (3.22), I can write:

$$\frac{L_f}{M} = \frac{\gamma}{1-\gamma} \frac{p_M^0}{w} \tag{3.23}$$

Substituting (3.17) and (3.18) in (3.16), I can write:

$$\frac{Y}{M} = A \left(\frac{K}{M}\right)^{\delta} \left(\frac{L_p}{M}\right)^{\alpha} \left(\frac{L_f}{M}\right)^{\gamma(1-\alpha-\delta)} e^{\lambda(1-\alpha-\delta)i_s} \tag{3.24}$$

From (3.23), I can write:

$$\left(\frac{L_f}{M}\right)^{\gamma(1-\alpha-\delta)} = \left(\frac{\gamma}{1-\gamma}\right)^{\gamma(1-\alpha-\delta)} \left(\frac{p_M^0}{w}\right)^{\gamma(1-\alpha-\delta)} \tag{3.25}$$

Define $L = L_p + L_f$ (note that neither L_p nor L_f are observable. I can only observe the total amount of labour used, L). Now, I can write:

$$\left(\frac{L_p}{M}\right)^{\alpha} = \left(\frac{L}{M} - \frac{\gamma}{1-\gamma} \frac{p_M^0}{w}\right)^{\alpha} = \left(\frac{L}{M}\right)^{\alpha} \left(1 - \frac{\gamma}{1-\gamma} \frac{p_M^0 M}{wL}\right)^{\alpha} \tag{3.26}$$

$$\left(\frac{p_M^0}{w}\right)^{\gamma(1-\alpha-\delta)} = \left(\frac{L}{M}\right)^{\gamma(1-\alpha-\delta)} \left(\frac{p_M^0 M}{wL}\right)^{\gamma(1-\alpha-\delta)} \tag{3.27}$$

Substituting (3.25), (3.26) and (3.27) in (3.24), I can write:

$$\frac{Y}{M} = A\left(\frac{K}{M}\right)^{\delta}\left(\frac{L}{M}\right)^{\alpha+\gamma(1-\alpha-\delta)}\left(1-\frac{\gamma}{1-\gamma}\frac{p_M^0 M}{wL}\right)^{\alpha}\left(\frac{\gamma}{1-\gamma}\right)^{\gamma(1-\alpha-\delta)} \left(\frac{p_M^0 M}{wL}\right)^{\gamma(1-\alpha-\delta)} e^{\lambda(1-\alpha-\delta)i_s} \tag{3.28}$$

Finally, defining $s = \frac{wL}{p_M^0 M+wL}$, I can write $\frac{p_M^0 M}{wL} = \frac{1-s}{s}$. And substituting in (3.28), I obtain:

$$\frac{Y}{M} = A\left(\frac{K}{M}\right)^{\delta}\left(\frac{L}{M}\right)^{\alpha+\gamma(1-\alpha-\delta)}\left(1-\frac{\gamma}{1-\gamma}\frac{1-s}{s}\right)^{\alpha}\left(\frac{\gamma}{1-\gamma}\right)^{\gamma(1-\alpha-\delta)} \left(\frac{1-s}{s}\right)^{\gamma(1-\alpha-\delta)} e^{\lambda(1-\alpha-\delta)i_s} \tag{3.29}$$

3.6.2. Empirical strategy

Empirical specification

Taking logs in expression (3.29) and using the approximation $\log\left(1-\frac{\gamma}{1-\gamma}\frac{1-s}{s}\right) \approx -\frac{\gamma}{1-\gamma}\frac{1-s}{s}$, I obtain:

$$\begin{aligned} y-m &= a+\delta(k-m)+\left[\alpha+\gamma\left(1-\alpha-\delta\right)\right](l-m)-\alpha\frac{\gamma}{1-\gamma}\frac{1-s}{s} \\ &\quad +\gamma\left(1-\alpha-\delta\right)\log\left(\frac{\gamma}{1-\gamma}\right)+\gamma\left(1-\alpha-\delta\right)\log\left(\frac{1-s}{s}\right)+\lambda\left(1-\alpha-\delta\right)i_s+u \end{aligned} \tag{3.30}$$

where y, m, k, and l are the logs of Y, M, K and L, respectively. The term u is an error term defined as in Section 3.3.

Expression (3.30) is the relevant equation to be estimated. It is an "augmented" production function. The analysis is carried out in a framework where the production function is augmented with a variable measuring the quality (degree of elaboration) of the intermediate input (term $\lambda\left(1-\alpha-\delta\right)i_s$).

Expression (3.30) embodies nonlinear restrictions in the parameters and, therefore, it is estimated using non-linear GMM estimation. Finally, I carry out all estimates in differences.

Estimation method

As I said before, expression (3.30) is estimated using non-linear GMM estimation. A GMM estimator minimizes a quadratic form in $\sum_{i=1}^{N} Z_i' u_i(\theta)$. The objective function is:

$$\min_{\theta} \left[\sum_{i=1}^{N} Z_i' u_i(\theta)\right]' \Lambda \left[\sum_{i=1}^{N} Z_i' u_i(\theta)\right] \tag{3.31}$$

where Z_i is the matrix of instruments and θ the set of parameters. A consistent estimator of θ (say $\widehat{\theta}$) can be obtained with

$$\Lambda = \left(\frac{1}{N}\sum_{i=1}^{N} Z_i' Z_i\right)^{-1} \tag{3.32}$$

where N is the number of firms, so that $\widehat{\theta}$ solves

$$\min_{\theta} \left[\sum_{i=1}^{N} Z_i' u_i(\theta)\right]' \left(\frac{1}{N}\sum_{i=1}^{N} Z_i' Z_i\right)^{-1} \left[\sum_{i=1}^{N} Z_i' u_i(\theta)\right] \tag{3.33}$$

The optimal estimator uses the weighting matrix $\Lambda = \left(\frac{1}{N}\sum_{i=1}^{N} Z_i' u_i(\widehat{\theta}) u_i(\widehat{\theta})' Z_i\right)^{-1}$.

In practice, expression (3.30) can be "concentrated out" for the estimation of parameters which enter linearly, and the non-linear search is over α, δ, γ and λ.

Testing overidentification restrictions

The objective function (3.31) evaluated at the optimal estimator and divided by N has an asymptotic chi-square distribution with L-K degrees of freedom, where L is the number of instruments and K the number of parameters to be estimated. I use it as a test of overidentifying restrictions.

Data and variables

Again, the data used correspond to the official survey "Encuesta sobre estrategias empresariales", ESEE, (Survey on Firm Strategies). In this case, I use a balanced panel. The sample used includes 198 firms with 10 consecutive observations per firm (1,980 observations are used).

To estimate equation (3.30), the data required for each firm include its output, capital, labour (measured through total hours of work) and intermediate inputs (see Appendix 3.A for detailed definitions). Moreover, to measure the importance of outsourcing in the firm (variable i_s), I use the proportion of intermediate consumptions that are subcontracted (see variable sr in Section 3.2)[80].

Finally, as I said before, p_M^0 is not observable, and hence $p_M^0 M$ is not observable. I use four different variables to approximate p_M^0: (i) deflated M (to approximate $p_M^0 M$); (ii) output price index; (iii) energy price index; (iv) services price index.

Table 3.A4 (see Appendix 3.C) gives some descriptive statistics of the key variables used (dependent variable, independent variables and instruments).

3.6.3. Estimation results

Table 3.8 presents the results of the non-linear GMM estimation of expression (3.30) in differences. All estimates include time dummies and some of them the capacity utilization variable (to control for input utilization). Across this table, a deflated M is used to approximate $p_M^0 M$.

Estimates in Table 3.8 are carried out taking labour and intermediate consumptions as endogenous variables. Lagged log-levels t-2 at each cross-section of both these inputs are used as instruments. Capital is treated as a predetermined variable, and hence, its lagged log-differences are valid instruments. I use as additional instruments the log-differences of hourly wage and the log-differences of materials price index.

Estimate a considers the proportion of intermediate consumptions that are subcontracted to be an exogenous variable, while estimates b, c, d, e and f consider it to be endogenous. Lagged differences of the proportion of intermediate consumptions that are subcontracted, log-differences of utilization of capacity, lagged log of utilization of capacity and the pro-

[80] The ESEE also provides information on service outsourcing, but it is four-year and qualitative information (use/no use of outside suppliers). The incorporation of service outsourcing into the measure of the indicator of the importance of outsourcing (i_s) is left to future research.

portion of temporary workers are used as instruments for this variable. The instruments used in each estimate are detailed in the notes to the table.

I obtain sensible and similar results for α and γ, i.e., coefficients for both “uses” of labour are similar. The elasticity of capital, which is difficultly estimated with variables in differences, seems particularly well estimated. Moreover, results for α, δ and γ are robust to the use of different instruments for i_s.

However, λ coefficients are estimated imprecisely, obtaining high standard errors. When the proportion of intermediate consumptions that are subcontracted is considered to be an exogenous variable (see estimate *a*), a very low coefficient is obtained. Furthermore, results for λ are not robust to the use of different instruments for i_s. In terms of λ, the preferred outcomes are estimates *b*, *d* and *e*. In these cases, λ takes a value around 1, although it is not significant. Further research is needed on improving estimation. An important step forward will be to obtain results for an unbalanced panel.

Regarding the test for overidentifying restrictions (or validity of the moment conditions based on the instruments), the test statistic is too high for the usual significance levels in the case of estimate *f*. The other values indicate the validity of the moment conditions, although there are differences in the significance levels.

Finally, Table 3.9 analyzes the robustness of the results to different measures for p_M^0. Estimate a is the same as estimate f in Table 3.8 (a deflated M is used to approximate $p_M^0 M$), while an output price index, an energy price index and a services price index are used to measure p_M^0 in estimates *b*, *c* and *d*, respectively. Again, results for α, δ and γ are robust to the different specifications.

The preferred outcome is estimate *a*. In this case, I obtain the most precise estimation of λ (a high standard error, but smaller than the estimated coefficient) and the best result in terms of the test of overidentifying restrictions.

Table 3.8. Production function estimates

Sample period: 1992-1999

N^o of firms: 198 (balanced panel. 10 observations per firm)

Estimation method: Non-linear GMM

	(a)	(b)	(c)	(d)	(e)	(f)
α	0.269(0.129)	0.280(0.130)	0.268(0.128)	0.312(0.137)	0.272(0.125)	0.236(0.124)
δ	0.247(0.098)	0.235(0.105)	0.248(0.099)	0.113(0.101)	0.249(0.105)	0.309(0.101)
$(1-\alpha-\delta)$	0.484	0.485	0.484	0.575	0.479	0.455
γ	0.265(0.143)	0.266(0.140)	0.266(0.142)	0.275(0.136)	0.267(0.141)	0.257(0.156)
$(1-\gamma)$	0.735	0.734	0.734	0.725	0.733	0.743
λ	0.036(0.075)	0.979(0.931)	0.108(0.148)	1.016(0.807)	0.976(0.923)	0.269(0.734)
Constant	−0.247(0.028)	−0.266(0.039)	−0.248(0.028)	0.001(0.008)	−0.010(0.008)	−0.248(0.034)
cu	0.054(0.006)	0.059(0.009)	0.054(0.006)	–	–	0.053(0.007)
Time dummies	Included	Included	Included	Included	Included	Included
$\chi^2(df)$	32.65(16)	29.04(15)	32.45(16)	27.70(17)	29.33(17)	36.81(16)

First step standard errors, robust to arbitrary autocorrelation over time and heteroskedasticity across firms shown in parentheses

Instruments are: l and m lagged log-levels t-2 at each cross-section; log-differences of hourly wage; log-differences of materials price index; lagged log-differences of k

Additional instruments are: Estimate (c): lagged differences of the proportion of intermediate consumptions that are subcontracted; Estimate (d): log-differences of utilization of capacity; Estimate (e): lagged log of utilization of capacity; Estimate (f): proportion of temporary workers

Table 3.9. Production function estimates. Robustness to different measures for p_M^0

Sample period: 1992-1999

N^o of firms: 198 (balanced panel. 10 observations per firm)

Estimation method: Non-linear GMM

	(a)	(b)	(c)	(d)
α	0.272(0.125)	0.256(0.150)	0.250(0.147)	0.242(0.147)
δ	0.249(0.105)	0.283(0.099)	0.314(0.108)	0.330(0.098)
$(1-\alpha-\delta)$	0.479	0.461	0.436	0.428
γ	0.267(0.141)	0.267(0.168)	0.265(0.166)	0.271(0.173)
$(1-\gamma)$	0.733	0.733	0.735	0.729
λ	0.976(0.923)	0.660(0.893)	0.712(0.965)	0.795(1.024)
Constant	−0.010(0.008)	−0.010(0.008)	−0.007(0.009)	−0.008(0.009)
Time dummies	Included	Included	Included	Included
$\chi^2(df)$	29.33(17)	31.93(17)	30.26(17)	29.59(17)

First step standard errors, robust to arbitrary autocorrelation over time and heteroskedasticity across firms shown in parentheses.

Instruments are: l and m lagged log-levels t-2 at each cross-section; log-differences of hourly wage; log-differences of materials price index; lagged log-differences of k; lagged log of utilization of capacity.

Different measures for p_M^0: Estimate (a): Approximate $p_M^0 M$ by using deflated M; Estimate (b): Approximate p_M^0 by using the output price index; Estimate (c): Approximate p_M^0 by using the energy price index; Estimate (d): Approximate p_M^0 by using the services price index.

To sum up, the main results up to here are as follows. Firstly, coefficients on both labour "uses", capital and intermediate consumptions are well estimated. Secondly, λ is estimated imprecisely, obtaining high standard errors. Moreover, results for this parameter seem to be less robust to different specifications. And thirdly, given $\widehat{\alpha}$, $\widehat{\delta}$, and $\widehat{\lambda}$, the coefficient onthe indicator of the importance of outsourcing (variable i_s) can be obtained. For example, using the results of estimate e in Table 3.8, the coefficient on i_s is equal to 0.467. However, this result should be viewed with some caveats (as I said before, λ is estimated imprecisely).

This line of research can be improved in at least three ways: by obtaining results for an unbalanced panel, by improving instrumentation (especially instruments for variable i_s), and by adding information on service outsourcing to improve the measure of the weight of outsourcing in the firm.

3.7. Conclusions

Innovation is a primary source of productivity growth, but a concept of innovation broader than technological product and process innovation is needed. As it is pointed out in the Oslo Manual (OECD, 2005), the concept of innovation should include marketing and organizational innovations. Organizational innovations on their own can have an important effect on productivity. In this sense, organizational innovations can increase the quality and efficiency of work, improve information sharing and the ability of the firm to use new technologies, as such increasing the productivity of investment in knowledge.

The aim of this chapter is to analyze the relationship between organizational innovation and productivity growth. I focus on the role of one of the most relevant organizational methods, outsourcing. Specifically, this study deals with outsourcing at the firm level and focuses on the role of contracting out manufacturing activities (production subcontracting).

In the existing empirical literature, outsourcing has been measured in many different ways. Most of the measures used are rough and there are few studies using data at the firm level. A feature of the firm-level data set that I use is the availability of a straight measure of production subcontracting. In this sense, I have information on firms' purchases of elaborated products and customized components from external suppliers.

In analyzing the effect of outsourcing on a firm's productivity, I first introduce a simple framework that specifies a production function considering the possibility of production subcontracting. The framework developed leads to the estimation of a production function depending on traditional inputs (labor, capital and materials) and an index of production subcontracting. Specifically, both the effect of first-time outsourcing on productivity and the effect of the intensity of production subcontracting can be analyzed.

Results for manufacturing as a whole show a positive effect of both the outsourcing decision and outsourcing intensity on productivity. When analyzing industry-level results, I find that outsourcing intensity has a positive effect on productivity, mainly for firms belonging to light industries (labor-intensive industries), while the decision to start (stop) outsourcing has, in most of the cases, the expected positive (negative) effect on productivity.

The chapter ends with a first attempt at modelling and estimating a more structural framework. This framework allows to identify two labour "uses" (labour used "directly" in the production of the final output and labour used in the production of the intermediate input). Results show plausible values for the elasticities of both labour "uses", capital and intermediate consumptions.

Appendix 3.A. Definitions of Variables

Capacity utilization: Yearly average rate of capacity utilization reported by the firm.

Capital stock: Capital at current replacement values is computed recursively from an initial estimate and the data on firms' investments in equipment goods (but not buildings or financial assets), actualized by means of a price index of capital goods, and using sectorial estimates of the rates of depreciation. Real capital is then obtained by deflating the current replacement values. Details on this variable can be found in Martín-Marcos and Suárez (1997).

Entrant firm: Dummy variable that takes the value 1 when the firm has been created during the period.

Exiting firms: Dummy variable that takes the value 1 when the firm is going to exit during the period (stop activity or stop manufacturing).

Hours of work: Total normal hours of work plus overtime minus lost hours, computed by multiplying hours per worker by the number of workers.

Hours per worker: Normal hours of work plus overtime minus lost hours per worker.

Industry dummies: Eighteen industry dummies (ESEE Industries. See Appendix B).

Intermediate consumption: Sum of purchases of materials and external services minus the variation of intermediate inventories. Nominal intermediate consumption is deflated by the firm's specific price index of intermediate consumption.

Merger and acquisition: Dummy variable that takes the value 1 in the years subsequent to a merger or acquisition.

Output: Goods and services production. Sales plus the variation of inventories deflated by the firm's output price index.

Production subcontracting: Dummy variable that takes the value 1 if the firm subcontracts production.

Price of energy: Paasche-type price index computed by starting from the percentage variations in the price of energy reported by the firms.

Price of intermediate consumption: Paasche-type price index computed by starting from the percentage variations in the prices of purchased materials, energy and services reported by the firms.

Price of output: Paasche-type price index computed by starting from the percentage price changes that the firm reports to have made in the markets in which it operates.

Price of services: Paasche-type price index computed by starting from the percentage variations in the price of services reported by the firms.

Scission: Dummy variable that takes the value 1 in the years subsequent to a scission.

Size: Two size dummies (fewer than or equal to 200 workers; and more than 200 workers).

Subcontracted purchases: Purchases of elaborated products or customized components. Nominal subcontracted purchases are deflated by the firm's specific price index of intermediate consumption.

Wage: Firm's hourly wage rate (total labour cost divided by effective total hours of work).

Workers: Approximation of the average number of workers during the year.

Appendix 3.B. Industry definitions

NACE Code (3-digit)	ESEE Industries	Industry breakdown
221 to 224	Ferrous and non-ferrous metals	1. Metals and metal products
311 to 319	Metal products	
240 to 249	Non-metallic mineral products	2. Non-metallic minerals
251 to 255	Chemical products	3. Chemical products
481, 482	Rubber and plastic products	
321 to 329	Industrial and agricultural machinery	4. Ind. and agric. machinery
330, 391 to 399	Office and data processing machinery	5. Office mach. and elec. goods
341 to 347, 351 to 355	Electrical goods	
361 to 363	Motor vehicles	6. Transport equipment
371, 372, 381 to 389	Other transport equipment	
413	Meats, meat preparation	7. Food, drink and tobacco
411, 412, 414 to 423, 429	Food products and tobacco	
424 to 428	Beverages	
431 to 439, 453 to 456	Textiles and clothing	8. Textile, leather and shoes
441, 442, 451, 452	Leather and leather products	
461 to 468	Timber, wood products	9. Timber and furniture
471 to 475	Paper and printing products	10. Paper and printing products
491 to 495	Other manufacturing products	11. Other manufacturing products

Appendix 3.C. Additional tables

Table 3.A1. Firms by industry and number of observations

Industry breakdown	No. of observations								
	3	4	5	6	7	8	9	10	Total
1. Metals and metal products	40	23	37	13	21	25	13	36	208
2. Non-metallic minerals	22	12	22	12	9	15	6	24	122
3. Chemical products	42	29	35	25	26	26	16	29	228
4. Ind. and agric. machinery	23	15	9	11	11	7	5	15	96
5. Office mach. and elec. goods	29	26	20	18	14	8	7	29	151
6. Transport equipment	21	21	22	8	11	12	3	18	116
7. Food, drink and tobacco	37	42	32	35	35	22	16	55	274
8. Textile, leather and shoes	69	31	31	25	25	36	9	43	269
9. Timber and furniture	20	13	15	18	9	16	4	12	107
10. Paper and printing products	20	16	16	14	13	16	11	16	122
11. Other manufacturing products	3	3	4	5	4	8	0	8	35
Total Industry	326	231	243	184	178	191	90	285	1728

Table 3.A2 Variable descriptive statistics

	Symbol	Mean	St. dev	Min	Max
Dependent variable					
Output (growth rate)	$\widetilde{y}$	0.038	0.259	-3.220	2.569
Explanatory variables					
Capacity utilization (growth rate)	cu	0.001	0.194	-2.833	2.944
Capital stock (growth rate)	$\widetilde{k}$	0.086	0.297	-2.619	4.362
Hours of work (growth rate)	$\widetilde{l}$	-0.002	0.193	-2.833	1.758
Intermediate consumptions[1] (growth rate)	$\widetilde{m}$	0.026	0.402	-4.375	3.682
Index of production subcontracting (growth rate)	sub	0.001	0.747	-8.650	9.171
Dummy indicating stopping outsourcing	$substop$	0.084		0	1
Dummy indicating starting outsourcing	$substart$	0.087		0	1
Industry dummies (ESEE Industries)					
Ferrous and non-ferrous metals		0.023		0	1
Metal products		0.100		0	1
Non-metallic mineral products		0.073		0	1
Chemical products		0.072		0	1
Rubber and plastic products		0.059		0	1
Industrial and agricultural machinery		0.054		0	1
Office and data processing machinery		0.008		0	1
Electrical goods		0.077		0	1
Motor vehicles		0.046		0	1
Other transport equipment		0.019		0	1
Meats, meat preparation		0.030		0	1
Food products and tobacco		0.114		0	1
Beverages		0.021		0	1
Textiles and clothing		0.119		0	1
Leather and leather goods		0.030		0	1
Timber, wood products		0.060		0	1
Paper and printing products		0.072		0	1
Other manufacturing products		0.023		0	1

[1]Without firm's purchases of elaborated products and customized components

Table 3.A2 (continued) Variable descriptive statistics

Explanatory variables			
Size dummies			
$\leq$ 200 workers	0.690	0	1
$>$ 200 workers	0.310	0	1
Time dummies			
1991	0.076	0	1
1992	0.088	0	1
1993	0.110	0	1
1994	0.120	0	1
1995	0.121	0	1
1996	0.125	0	1
1997	0.125	0	1
1998	0.126	0	1
1999	0.110	0	1

Table 3.A3. Production function estimates. Robustness checks

Equation: $\widetilde{y} = \alpha + \delta\widetilde{k} + \phi_1\widetilde{l} + \phi_2\widetilde{m} + \phi_3 sub + \beta_1 substop + \beta_2 substart + \widetilde{v}$

Sample period: 1992-1999

N^o of firms: 1728

Estimation method: GMM[1]

Dependent variable: $\widetilde{y}$

	a		*b*		*c*	
Independent variables[2]	*a*.1	*a*.2	*b*.1	*b*.2	*c*.1	*c*.2
Constant	0.02(2.5)	0.017(2.5)	0.018(2.2)	0.016(2.2)	0.02(2.1)	0.015(1.96)
$\widetilde{k}$	0.13(1.45)	0.17	0.15(1.6)	0.19	0.15(1.59)	0.20
$\widetilde{l}$	0.39(4.1)	0.39(4.2)	0.38(4.0)	0.38(4.0)	0.39(4.2)	0.40(4.3)
$\widetilde{m}$	0.42(5.6)	0.44(6.3)	0.42(5.1)	0.43(5.9)	0.37(5.2)	0.40(6.0)
sub	0.11(3.7)	0.12(2.9)	0.11(3.4)	0.11(3.6)	0.10(3.2)	0.10(3.4)
substop	−0.07(−6.3)	−0.07(−6.7)	−0.07(−6.0)	−0.07(−6.4)	−0.06(−5.8)	−0.07(−6.3)
substart	0.06(4.2)	0.06(4.4)	0.06(3.9)	0.06(4.2)	0.05(3.8)	0.05(4.1)
cu	0.08(3.0)	0.07(2.9)	0.08(2.9)	0.07(2.9)	0.09(3.4)	0.08(3.4)
Industry dummies[3]	Included	Included	Included	Included	Included	Included
Time dummies[3]	Included	Included	Included	Included	Included	Included
Size dummies[3]	Included	Included	Included	Included	Included	Included
m_1	−8.8	−9.2	−8.8	−9.2	−8.2	−8.6
m_2	−1.7	−1.6	−1.7	−1.6	−1.8	−1.7
Sargan test (df)	30.5(28)	30.6(29)	22.6(21)	22.2(22)	24.4(21)	24.0(22)
Wald test (df)	0.35(1)		0.22(1)		0.6(1)	

Heteroskedasticity robust t-ratios shown in parentheses.

[1]Instruments are:

Estimate (a): l lagged levels t-2 and t-3; m and sub-lagged levels t-2; and lagged log-differences of k.

Estimate (b): l, m and sub-lagged levels t-2; and lagged log-differences of k.

Estimate (c): l, m and sub-lagged levels t-2; lagged log-differences of k; and log of price of intermediate consumptions.

[2]Wald test allows us to accept $\delta + \phi_1 + \phi_2 = 1$. Estimates a.2, b.2, and c.2 impose this constraint.

[3]18 industry dummies (ESEE Industries), 8 year dummies and 2 size dummies, with the coefficients of each set constrained to add up to zero; dummies for entering and exiting firms, as well as mergers and scissions, also included.

Table 3.A4. Variable descriptive statistics

		Balanced Panel (198 firms)			
Variable	Symbol	Mean	St. dev	Min	Max
Output (logs)	y	13.723	1.710	8.862	17.748
Capital stock (logs)	k	11.869	2.039	4.727	17.560
Hours of work (logs)	l	4.862	1.364	1.946	8.987
Intermediate consumptions (logs)	m	13.210	1.805	6.842	17.571
Index of production subcontracting	i_s	0.096	0.172	0.000	0.997
Capacity utilization (logs)	cu	4.375	0.207	2.890	4.605
Output price index (logs)		−0.004	0.087	−0.470	0.368
User cost of capital		0.025	0.046	0.000	0.200
Hourly wage (logs)		7.472	0.465	5.143	8.825
Energy price index (logs)		−0.004	0.094	−0.435	0.286
Services price index (logs)		−0.006	0.110	−0.544	0.318
Temporary workers proportion		0.197	0.199	0.000	0.934
Effective hours per worker (logs)		7.486	0.061	6.380	7.800

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APPENDIX. RESUMEN: OBJETIVOS, RESULTADOS, APORTACIONES Y CONCLUSIONES

A.1. Introducción

Las actividades de innovación realizadas por las empresas y el impacto de dichas actividades son de interés primordial tanto para economistas como para responsables de política económica. El análisis de estas actividades requiere el conocimiento tanto de los factores que afectan a la capacidad innovadora de las empresas como el conocimiento del impacto de las actividades innovadoras en la actividad económica de las empresas a través de cambios en la demanda y en sus costes.

Esta tesis estudia dos de los temas de investigación más relevantes de la Economía de la Innovación: (i) la cooperación en actividades innovadoras, y (ii) la relación entre innovación y productividad.

A.1.1. Cooperación en actividades innovadoras

Las actividades innovadoras de las empresas dependen en gran medida de la variedad y estructura de sus vínculos con las fuentes de información y conocimiento, fuentes tecnológicas, y fuentes de recursos humanos y financieros. Cada uno de estos vínculos conecta a la empresa con otros agentes del Sistema de Innovación, tales como laboratorios comerciales, universidades, departamentos de política económica, reguladores, institutos de investigación públicos, competidores, proveedores y clientes. Estos flujos de conocimiento entre las empresas y otras organizaciones tienen un papel importante en el desarrollo y la difusión de innovaciones.

El Manual de Oslo (OCDE, 2005) identifica tres tipos de vínculos entre las empresas y su entorno: (i) fuentes de información abiertas, (ii) adquisición de conocimiento y de tecnología, y (iii) cooperación en actividades innovadoras. En primer lugar, las fuentes de información abiertas proveen la información disponible que no requiere la compra de tecnología o de derechos de propiedad intelectual, ni de la interacción con la fuente. En segundo lugar, la adquisición de conocimiento y tecnología es la compra de conocimiento externo, bienes de capital (maquinaria, equipo, software) y servicios. En tercer lugar, la cooperación en actividades de innovación consiste en la cooperación activa con otros agentes del Sistema de Innovación (por ejemplo, universidades, empresas o institutos de investigación públicos) con el objetivo de realizar actividades innovadoras. Es decir, estas actividades consisten en acuerdos con otros agentes por los cuales las empresas comparten los costes y los beneficios de proyectos de innovación.

Con el fin último de fomentar la innovación, recientemente se ha prestado un interés creciente a la cooperación en actividades de innovación (véase, entre otros, a Dodgson (1994), Hagedoorn et al. (2000), Hagedoorn (2002), y Tyler y Steensma (1995)).

Una característica importante de esta tipo de actividades de cooperación es su interacción con temas de Política de la Competencia. Desde el trabajo seminal de Schumpeter (1943), la relación entre competencia e innovación ha sido una cuestión de interés tanto para economistas como para responsables de política económica. En este sentido, el nivel de competencia en los mercados tiene una gran influencia en el surgimiento y la difusión de la tecnología y de la innovación.

El análisis económico sugiere la existencia de una serie de dificultades para alcanzar el nivel óptimo de las actividades innovadoras bajo competencia perfecta en los mercados[81]. El carácter del input "conocimiento" (libremente disponible una vez revelado), la existencia de costes fijos altos, y en muchos casos costes hundidos, y la incertidumbre asociada a los resultados de las actividades de innovación hacen que las empresas tengan pocos incentivos a la hora de asignar recursos a este tipo de actividad que, al mismo tiempo, produce importantes externalidades positivas hacia otras empresas y consumidores. Por otra parte, tal y como numerosos estudios empíricos han demostrado (Geroski (1995), Nickell (1996), Blundell, Griffith y Van Reenen (1999), entre otros), la presión competitiva parece en muchas circunstancias estimular fuertemente las actividades innovadoras y la introducción de inno-

[81] Ver, entre otros, Martin (2002, Capítulo 14), Dasgupta y Stiglitz (1980), Aghion y Howitt (1992).

vaciones por parte de la empresas.

En este contexto, uno de los aspectos más interesantes de la cooperación en actividades de innovación es su importancia como factor de generación, mejora, apropiación y protección de los flujos de información. Por lo tanto, este tipo de acuerdos es una guía útil en aspectos de regulación normativa, que deben tratar de consolidar mecanismos de incentivos y, al mismo tiempo, no obstaculizar la competencia en los mercados.

Por lo tanto, es importante entender qué tipo de empresas son propensas a cooperar en actividades de innovación, los motivos de dicha actividad y hasta que punto la política económica es eficaz como estímulo de estas actividades. En este sentido, los dos primeros capítulos de esta tesis presentan evidencia sobre los determinantes de la cooperación en actividades innovadoras. El primero explora los determinantes en el caso de las empresas manufactureras españolas, mientras que el segundo investiga los determinantes de este tipo de acuerdos en cuatro países europeos: Francia, Alemania, España y Reino Unido.

A.1.2. Innovación y productividad

El mal comportamiento de la productividad en Europa en relación a los EEUU ha sido una de las principales preocupaciones de política económica en Europa. En este sentido, uno de los objetivos de la "Estrategia de Lisboa" es corregir la baja productividad y el estancamiento del crecimiento económico en la UE. Tal y como se señala en Sapir et al. (2003): "En la UE, ha habido una disminución constante del crecimiento década tras década y el PIB per cápita se ha estancado alrededor del 70% del nivel de los EEUU desde el principios de los 80".

En las primeras tres décadas después de la Segunda Guerra Mundial, Europa estableció una reputación envidiable en relación a su crecimiento económico elevado y a su nivel alto de protección social. El crecimiento económico en los países europeos durante la posguerra se basó en la implantación generalizada de tecnologías maduras con implicaciones organizativas bien conocidas y una difusión rápida de la "mejor práctica". Es decir, la convergencia con los niveles de los EEUU se basó en la inversión y acumulación de factores productivos, y en la imitación de tecnologías.

El bajo crecimiento económico en la UE durante las últimas décadas es síntoma de su fracaso en transformarse en una economía sustentada en la innovación. Un sistema construido en base a la asimilación de tecnologías existentes, la producción en masa y una estructura industrial dominada por empresas grandes no encaja en el mundo de hoy, caracterizado por la globalización económica y por una fuerte competencia internacional (Sapir et al. (2003)).

Los países europeos necesitan orientarse hacia un crecimiento basado en la innovación. La innovación afecta al funcionamiento y resultados de las empresas a través de una variedad de canales, que van desde los efectos de la innovación sobre ventas y cuotas de mercado a los cambios en la productividad y eficiencia de las empresas. Además, la innovación tiene otros efectos importantes a nivel industrial y nacional tales como: cambios en la competitividad internacional y en la productividad total de los factores, la aparición de flujos de información derivados de las innovaciones empresariales y el incremento de flujos de conocimiento a través de las redes.

Tanto académicos como responsables de política económica han remarcado la importancia de la inversión en Investigación y Desarrollo (I+D) como motor de crecimiento de la productividad de largo plazo. En relación con la literatura académica sobre este tema, desde Griliches (1979), muchos estudios empíricos se han centrado en la relación entre I+D y productividad[82], y en el papel de las innovaciones tecnológicas de proceso y de producto como impulsores de la productividad[83]. En respuesta a estas inquietudes, la UE se ha fijado el objetivo de aumentar el gasto en I+D hasta el 3% del PIB antes de 2010 (este objetivo es parte de la "Estrategia de Lisboa").

Sin embargo, es necesario un marco más amplio que aquél en el que sólo se considera la innovación de producto y de proceso. En este sentido, la tercera edición del Manual de Oslo (OCDE, 2005) amplía la definición de la innovación para incluir, además de la innovación de producto y de proceso, dos tipos adicionales de innovación: (i) la innovación

[82] Griliches (1995) contiene una revisión de esta literatura.

[83] Por ejemplo, Crépon et al. (1998) proponen un modelo estructural para analizar la relación entre gastos en I+D, innovación y productividad.

organizativa y (ii) la innovación de la comercialización. Considerando estos dos tipos de innovación, se obtiene un marco más completo para tener en cuenta de forma más precisa los cambios que afectan al funcionamiento de las empresas y que contribuyen a la acumulación de conocimiento.

El tercer capítulo de esta tesis contribuye a la literatura que estudia la relación entre innovación y productividad analizando el efecto que la innovación organizativa tiene sobre la productividad. Una innovación organizativa (véase OCDE, 2005) es la puesta en práctica de un nuevo método de organización. Éstos pueden ser: (i) cambios en las prácticas empresariales (por ejemplo, sistemas de gestión de los conocimientos nuevos o mejorados de manera significativa), (ii) cambios en la organización del trabajo dentro de la empresa (por ejemplo, la puesta en práctica de métodos nuevos para distribuir responsabilidades y la autonomía en la toma de decisiones por parte de los trabajadores), o (iii) cambios en las relaciones con el exterior (es decir, la puesta en práctica de maneras nuevas de organizar las relaciones con otras empresas o instituciones públicas).

Los cambios en los métodos de organización pueden mejorar la eficiencia y la calidad de las actividades de las empresas, y de este modo pueden incrementar la demanda y reducir los costes. Hay un número cada vez mayor de estudios que sugieren un efecto significativo y positivo de diversos tipos de innovación organizativa en la productividad. Por ejemplo, Black y Lynch (2004) aportan uno de los resultados más significativos sobre la relación entre innovación organizativa y crecimiento. Estos autores encuentran que el 30% del crecimiento del output en el sector manufacturero de EEUU durante el período 1993-1996 se debió a prácticas organizativas.

El tercer capítulo se centra en el papel de uno de los métodos organizativos más relevantes, el outsourcing (externalización o subcontratación). En este sentido, la tercera edición del Manual de Oslo (OCDE, 2005) considera la "externalización o subcontratación de actividades económicas de producción, distribución, contratación de personal y contratación de servicios" un método nuevo de organización en las relaciones exteriores de las empresas.

A.2. Objetivos y metodología

Tal y como se dijo en la introducción, el objetivo de esta tesis es el estudio de dos de los temas de investigación más relevantes relacionados con la Economía de la Innovación: (i) la cooperación en actividades de innovación, y (ii) la relación entre innovación y productividad.

En concreto, el objetivo de la primera línea de investigación es el estudio empírico de los determinantes de la cooperación en actividades de innovación. El primer capítulo de la tesis se centra en el estudio de estos determinantes en el caso de las empresas manufactureras españolas, mientras que el segundo capítulo realiza una comparación internacional de dichos determinantes utilizando datos de Alemania, España, Francia y Reino Unido. En ambos capítulos se utilizan datos procedentes de la Community Innovation Survey (CIS).

La segunda línea de investigación (tercer capítulo de la tesis) se centra en el análisis del impacto de una de las innovaciones organizativas más relevantes, el outsourcing, sobre la productividad a nivel de empresa. En este caso se utilizan datos de la Encuesta sobre Estrategias Empresariales (ESEE).

Antes de resumir los objetivos y metodología de cada uno de los capítulos se realiza una breve descripción de las bases de datos utilizadas.

A.2.1. Bases de datos utilizadas

Community Innovation Survey (CIS)

Los datos utilizados en los dos primeros capítulos corresponden a la tercera oleada de la Community Innovation Survey (CIS) que tuvo lugar en el año 2001.

La CIS se realiza cada cuatro años y tiene como objetivo estudiar las actividades innovadoras de los países europeos. La encuesta se realiza siguiendo las directrices metodológicas definidas en el Manual de Oslo de la OCDE y su contenido está armonizado entre los diferentes países europeos, lo que permite la comparabilidad internacional.

Esta encuesta facilita información a nivel de empresa sobre la estructura del proceso de innovación (I+D y otras actividades innovadoras) y permite mostrar la relación entre dicho proceso y la estrategia tecnológica de las empresas, los factores que influyen en su capacidad para innovar y el rendimiento económico de la empresa.

La información que contiene se refiere a adquisición de nuevas tecnologías, innovaciones tecnológicas, actividades de I+D, gastos en innovación, regionalización de los gastos de innovación, impacto económico de la innovación tecnológica, objetivos de la actividad innovadora, fuentes de ideas innovadoras, obstáculos a la innovación y otras innovaciones no tecnológicas.

La encuesta va dirigida a empresas industriales, de la construcción y de los servicios de diez o más asalariados, cuya actividad económica principal se corresponde con las secciones C a la O de la Clasificación Nacional de Actividades Económicas de 1993 Rev 1.

En España, la CIS toma le nombre de Encuesta sobre Innovación Tecnológica en las Empresas y es realizada por el INE.

Encuesta sobre Estrategias Empresariales (ESEE)

En el tercer capítulo se utilizan datos procedentes de la Encuesta sobre Estrategias Empresariales (ESEE).

La ESEE es una encuesta de panel a empresas industriales manufactureras que, iniciada con los datos correspondientes a 1990, se ha venido realizando hasta la actualidad. Esta encuesta fue diseñada por el Programa de Investigaciones Económicas (PIE) de la Fundación Empresa Pública (FEP). En la actualidad es cofinanciada por el Ministerio de Industria, Turismo y Comercio y por la Fundación SEPI.

La ESEE se basa en una muestra dinámicamente representativa (articulada en dos grandes submuestras, empresas con más y menos de 200 trabajadores), a la que se ha investigado en un conjunto amplio de aspectos relacionados con temas de economía industrial (incluyendo las actividades innovadoras)[84]. La selección inicial de empresas se realizó combinando criterios de exhaustividad y de muestreo aleatorio. En el primer grupo se incluyeron las empresas de más de 200 trabajadores, a las que se requirió su participación. El segundo grupo quedó formado por las empresas con empleo comprendido entre 10 y 200 trabajadores, que fueron

[84] Una descripción detallada de esta encuesta se encuentra en Fariñas y Jaumandreu (1999).

seleccionadas por muestreo estratificado, proporcional con restricciones y sistemático con arranque aleatorio.

En cuanto a su contenido, la ESEE está orientada a recoger información sobre las estrategias de las empresas, es decir sobre aquellas decisiones que adoptan en relación a los instrumentos de competencia a su alcance. De una forma general, podemos clasificar la información que proporciona la ESEE en los siguientes apartados: (i) Actividad de la empresa, productos y procesos de fabricación, (ii) Clientes y proveedores, (iii) Costes y precios, (iv) Mercados, (v) Actividades tecnológicas, (vi) Comercio exterior, (vii) Empleo y (viii) Datos contables.

A.2.2. Objetivos y metodología en el estudio de los determinantes de la cooperación en I+D: El caso de las empresas manufactureras españolas

En comparación con el resto de países europeos, el sistema español de innovación está en una fase de desarrollo menos avanzada. En un estudio reciente de Abramovsky et al. (2004), en el que se comparan las actividades y resultados de la innovación para Alemania, España, Francia y Reino Unido utilizando datos de la tercera oleada de la Community Innovation Survey (CIS3), se pone de manifiesto que España presenta el menor porcentaje de empresas con gastos en innovación. Esta diferencia es especialmente importante en el caso de los gastos de I+D interna. Además, la intensidad en I+D (ratio de los gastos en I+D interna sobre cifra de negocios de la empresa) en España es, aproximadamente, un tercio del esfuerzo en Alemania, Francia o Reino Unido, y esta diferencia es sistemáticamente mayor en los sectores intensivos en tecnología. Igualmente, España presenta la menor proporción de empresas con acuerdos de cooperación en actividades de innovación.

Este diferencial en el desarrollo de las actividades innovación hace aún más interesante el estudio del fenómeno de la cooperación en innovación para el caso español. El fomento de las actividades de cooperación, dado su carácter de catalizador de la innovación, puede ser un instrumento útil y, por tanto, necesario en la convergencia de España con la media europea.

El objetivo concreto de este capítulo es el estudio empírico de los determinantes de la cooperación en actividades de I+D utilizando datos de empresas españolas. El trabajo se centra en el estudio de la importancia sobre la propensión a cooperar de factores tales como: los flujos de información o "spillovers", la capacidad de absorción de la empresa, el reparto de costes y riesgo entre los socios del acuerdo, el intercambio de conocimientos, etc.

Como se dijo anteriormente, se utilizan datos de la Encuesta sobre Innovación Tecnológica en las Empresas del año 2001.

En este estudio se aplican técnicas microeconométricas que permiten hacer tests sobre la posible endogeneidad de variables explicativas que en otros estudios son consideradas endógenas a priori. Concretamente, se aplica un método de estimación máximo verosímil condicional que tiene en cuenta los posibles problemas de endogeneidad.

A.2.3. Objetivos y metodología en el estudio de los determinantes de la cooperación en actividades de innovación: Evidencia para cuatro países europeos

Este segundo capítulo analiza la cooperación en actividades de innovación en cuatro países europeos, Francia, Alemania, España y Reino Unido. Una vez más la fuente de los datos es la Community Innovation Survey, lo que permite comparar los resultados obtenidos entre los diferentes países. En concreto, se utilizan datos de la tercera edición de la CIS (año 2001).

En este capítulo se examina, entre otros, el papel de los flujos de conocimiento, el reparto de costes y riesgo, y la importancia de las ayuda públicas en la decisión de establecer acuerdos de cooperación en actividades de innovación. En este estudio se utilizan datos tanto de empresas manufactureras como de servicios.

El problema de endogeneidad de alguna de las variables explicativas es tratado aplicando un método de estimación en dos etapas.

A.2.4. Objetivos y metodología en el estudio del impacto del outsourcing en la productividad

El tercer capítulo analiza la relación entre innovación organizativa y productividad. En concreto, el estudio se centra en el papel de una de las innovaciones organizativas más relevantes, el outsourcing. El outsourcing implica la modificación de la “frontera” de la empresa y debe considerarse como un fenómeno de innovación organizativa cuya finalidad última es incrementar la flexibilidad y eficiencia de las empresas. Específicamente, este capítulo se centra en el outsourcing a nivel de empresa y en el papel de la subcontratación de la producción (compras a terceros de productos terminados o componentes a medida para la empresa).

Para realizar este análisis, se desarrolla y estima un marco teórico sencillo que justifica la incorporación de medidas de outsourcing a la especificación de una función de producción “tradicional”. Este marco implica la estimación de una función de producción dependiendo de los inputs tradicionales (trabajo, capital y materiales) y de un índice de subcontratación de la producción.

La estimación de dicha función de producción se lleva a cabo teniendo en cuenta la existencia de variables endógenas y predeterminadas. Para ello se aplica el Método Generalizado de Momentos, GMM (ver Arellano y Bond (1991) para una descripción de este método).

Este marco teórico sencillo tiene algunas limitaciones que son tratadas en la última parte del capítulo. En este sentido, el tercer capítulo finaliza con una primera tentativa de modelizar y estimar un marco más estructural en el que se especifica una función de producción considerando la posibilidad de la subcontratación de la producción. Este marco permite identificar dos “usos” para el trabajo (trabajo usado “directamente” en la producción de bien final y el trabajo usado en la producción de un input intermedio). En este caso la ecuación relevante a estimar presenta restricciones no lineales en los parámetros, por lo que en la estimación se utiliza GMM no lineal.

A.3. Aportaciones y resultados principales

A.3.1. Determinantes de la cooperación en I+D: Evidencia para las empresas manufactureras españolas

Aportaciones

En primer lugar, este trabajo pone de manifiesto que un tratamiento riguroso de la endogeneidad tiene una gran importancia. El método de estimación utilizado permite hacer tests de endogeneidad sobre variables explicativas que en otros estudios se asumen endógenas a priori. Se obtiene que la elección de una "estructura apropiada" de endogeneidad es crucial y tiene consecuencias importantes para las estimaciones.

En segundo lugar, la muestra de empresas utilizada es muy interesante. Por una parte, se utiliza una muestra amplia compuesta por 2.518 empresas. Este tamaño muestral permite obtener estimaciones precisas y tests de hipótesis fiables. Por otra parte, tal y como se dijo anteriormente, el sistema español de innovación está en una fase de desarrollo menos avanzada comparado con la mayoría de los países europeos. Debido a que la cooperación en actividades en I+D es una práctica útil para mejorar el funcionamiento de la innovación empresarial, este diferencial respecto al resto de países europeos hace aún más interesante el estudio de los factores que estimulan la cooperación en este tipo de actividades. Además, el sector manufacturero español está compuesto mayoritariamente por empresas pequeñas de sectores poco intensivos en tecnología. En general, los estudios demuestran que las empresas grandes y en sectores de tecnología alta presentan una mayor propensión a cooperar en actividades de I+D, y por lo tanto es de gran interés estudiar este tipo de cooperación en un contexto como el español, caracterizado por la existencia de empresas pequeñas y de sectores poco intensivos en tecnología.

Resultados principales

Los resultados principales que se obtienen son los siguientes:

i) Los "spillovers" recibidos[85] tienen un efecto positivo en la probabilidad de cooperar. En este sentido, cuanto mayor sea la información libremente disponible para la empresa, mayores son los beneficios que se pueden explotar a través de acuerdos de cooperación.

ii) La apropiabilidad a nivel de empresa tiene un efecto positivo en la propensión a cooperar. Cuanto mayor sea el control a través de métodos estratégicos de protección[86] de los flujos de información por parte de la empresa, mayor es la propensión a cooperar (la eficacia de los métodos estratégicos de protección disminuye el riesgo de comportamientos oportunistas por parte de otras empresas). Sin embargo, el nivel de eficacia de los métodos legales[87] a nivel industria parece tener un efecto negativo sobre la cooperación. En este sentido, una excesiva protección a través de estos métodos puede dificultar la internalización de los flujos de información que se comparten con los socios de los acuerdos.

iii) Para España, la posibilidad de compartir costes y riesgos es el principal determinante de la cooperación en actividades de I+D. Este hecho puede ser reflejo de la falta de inversión privada o la escasez de capital riesgo, lo que lleva a las empresas a compartir los costes y riesgos de las actividades de innovación con otras empresas o instituciones.

iv) La capacidad de absorción de la empresa y la capacidad tecnológica de la empresa tienen efectos positivos sobre la probabilidad de cooperar. Cuanto mayor sean estas variables, mayores son los beneficios potenciales de la cooperación con otras empresas o instituciones.

v) Diferenciando por tipo de socio, caben destacar tres hechos. En primer lugar, en el caso de la cooperación con empresas competidoras, la variable que tiene un efecto mayor sobre la probabilidad de cooperar es la apropiabilidad. Es decir, la capacidad de control a través de métodos estratégicos de protección de los flujos de información es crucial en la decisión de

[85]La variable "spillovers" recibidos se define como la importancia para el proceso de innovación de las empresas de las fuentes de información accesibles públicamente. En concreto, estas fuentes de información son Conferencias profesionales, reuniones y revistas especializadas, y ferias y exhibiciones.

[86]Estos métodos incluyen: Secreto de fábrica, complejidad en el diseño y tiempo de liderazgo sobre los competidores.

[87]Estos métodos incluyen: Patentes, registros de modelos de utilidad, marcas de fábrica y derechos de autor.

cooperar con competidores directos. En segundo lugar, los "spillovers" recibidos sólo tienen un efecto positivo en la probabilidad de cooperar con instituciones de investigación. En este sentido, la información libremente disponible para la empresa sólo tiene un efecto positivo en la cooperación con socios tales como universidades, laboratorios comerciales, organismos públicos de investigación, etc. En tercer lugar, la posibilidad de compartir costes y riesgos es el principal determinante de la cooperación en actividades de I+D con proveedores o clientes y con instituciones de investigación.

A.3.2. Un análisis de los acuerdos de cooperación en innovación: Evidencia para cuatro países europeos

Aportaciones

Las aportaciones principales de este estudio respecto a la literatura existente y respecto al capítulo anterior son las siguientes:

i) Se obtiene resultados comparables para cuatro grandes países europeos (Alemania, España, Francia y Reino Unido). Esto es posible gracias a la utilización de datos procedentes de la tercera edición de la Community Innovation Survey (CIS), encuesta para la que se dispone de un cuestionario armonizado entre los países europeos.

ii) Además de las empresas manufactureras, se analiza el sector servicios. La utilización de datos del CIS es particularmente adecuado para analizar las actividades de innovación en el sector servicios ya que esta encuesta considera una perspectiva amplia de la innovación (más allá del concepto de gasto de I+D interna).

iii) Se analiza el efecto del apoyo financiero público para actividades de innovación (préstamos, subvenciones) en la propensión a cooperar en actividades de innovación.

Resultados principales

Los resultados principales obtenidos son:

i) Se encuentra evidencia a favor de una relación positiva entre el grado en el que las empresas pueden beneficiarse de los flujos de información externos ("spillovers" recibidos[88]) y la propensión a establecer acuerdos de cooperación en actividades de innovación. Este efecto es especialmente importante a la hora de cooperar con organismos de investigación, mientras que esta propensión disminuye a la hora de cooperar con empresas competidoras pertenecientes a la misma industria.

ii) También se encuentra evidencia a favor de un efecto positivo de la importancia de los métodos estratégicos de protección (secreto de fábrica, complejidad en el diseño y tiempo de liderazgo sobre los competidores). Este efecto es significativo para el caso de acuerdos de cooperación con organismos de investigación, con proveedores y con clientes. El efecto es menos importante en el caso de cooperación con competidores.

iii) Los resultados para el caso español son sensiblemente diferentes, especialmente al compararlos con los obtenidos para Alemania y Reino Unido. Para España se encuentra que, especialmente en el sector industrial, la empresas más grandes son más propensas a cooperar, y que las empresas cooperan para compartir los costes y los riesgos derivados de las actividades de innovación. Este resultado puede derivarse de diferencias entre España y el resto de países analizados en el mercado de capitales y en la disponibilidad y coste de las fuentes de financiación externas para actividades de innovación.

iv) El hecho de recibir apoyo financiero público tiene un efecto positivo sobre la probabilidad de cooperar. Este efecto es especialmente importante en el caso de la cooperación con organismos de investigación (como universidades y organismos públicos de investigación). Esto coincide con la orientación que se quiere dar a la financiación pública para la innovación, la cual intenta incentivar este tipo de acuerdos de cooperación y promover la transferencia tecnológica desde las universidades a las empresas.

[88] Importancia para el proceso de innovación de las empresas de las fuentes de información accesibles públicamente Conferencias profesionales, reuniones y revistas especializadas, y ferias y exhibiciones.

A.3.3. Innovación organizativa y productividad: un análisis del impacto del outsourcing en la productividad de las empresas

Aportaciones

En primer lugar, en este estudio se propone un marco teórico que permite estimar el impacto del outsourcing en la productividad. Concretamente, el marco desarrollado permite evaluar el impacto de la decisión de subcontratación (empezar y dejar de subcontratar) y de la intensidad de la subcontratación.

En segundo lugar, mientras que la literatura empírica existente sobre este tema se ha centrado en los efectos sobre la productividad a nivel industrial y nacional, este análisis se lleva a cabo a nivel de empresa. Además se utilizan datos de panel, lo que permite tener en cuenta la heterogeneidad inobservada entre las empresas y analizar efectos temporales.

En tercer lugar, la base de datos utilizada permite utilizar una medida directa de la subcontratación de la producción. En concreto, se tiene información sobre compras a terceros de productos terminados o componentes a medida para la empresa. En este sentido, en la literatura empírica, el outsourcing se ha medido de modos diversos y utilizando diferentes perspectivas. La mayor parte de estas aproximaciones utilizan información a nivel de industria y procedentes de tablas input-output. Además, en muchos casos se utilizan medidas imprecisas.

Resultados principales

Las conclusiones principales de las estimaciones realizadas son las siguientes:

i) El outsourcing tiene un efecto positivo sobre la productividad. Se obtiene un efecto positivo del índice de subcontratación en la productividad de las empresas. Concretamente, se obtiene una elasticidad del output respecto a la intensidad de la subcontratación de 0,14.

ii) No sólo la intensidad en la subcontratación, sino también la decisión de empezar o dejar de subcontratar tiene impacto. En este sentido, empezar a subcontratar tiene un efecto positivo sobre la productividad de las empresas, mientras que dejar de subcontratar tiene el efecto contrario.

iii) El efecto positivo del outsourcing sobre la productividad es especialmente importante en los sectores intensivos en trabajo.

iv) Se obtienen estimaciones razonables de las elasticidades de los inputs tradicionales (capital, trabajo y materias primas).

A.4. Conclusiones e implicaciones de política económica

Los análisis de la productividad a nivel agregado muestran sistemáticamente un crecimiento menor de la economía europea en comparación con los EEUU (ver, por ejemplo, Scarpetta et al. (2000)). Este hecho, especialmente importante en ciertos sectores de servicios intensivos en el uso de tecnologías de la información, es de gran preocupación y ha sido objeto de numerosas discusiones sobre la capacidad de la economía europea para desarrollar, difundir y aplicar las nuevas tecnologías, y sobre su capacidad para convertir dichas tecnologías en fuente de crecimiento económico. La "Estrategia de Lisboa", que es la respuesta de los países de la UE a este reto, marcó el objetivo estratégico de convertir antes del 2010 la economía de la UE en "la economía del conocimiento más competitiva y dinámica del mundo, capaz de alcanzar un crecimiento económico duradero acompañado por una mejora cuantitativa y cualitativa del empleo y una mayor cohesión social". El desarrollo de estas políticas continúa siendo en la actualidad un tema de interés primordial. Los resultados de esta tesis doctoral, que se centran en el análisis de la cooperación en actividades de innovación y en el efecto de la innovación en la productividad, tienen algunas implicaciones generales sobre estas políticas.

La premisa de partida es, tal y como muestran los resultados obtenidos en esta tesis, que la innovación tiene un efecto positivo sobre la productividad. La cuestión es cómo reforzar de forma adecuada este hecho. La investigación que se presenta en este estudio sobre innovación y productividad ha contribuido a la literatura existente analizando el efecto de uno de los tipos de innovación organizativa, el outsourcing, sobre la productividad.

La cooperación en actividades de innovación, aún desigualmente implantada en los diferentes países de la UE, se ha revelado como un vehículo adecuado para hacer frente a los desafíos derivados del progreso tecnológico mediante la obtención de innovaciones. Tanto la OCDE como la UE apoyan la idea de reforzar los lazos entre la industria y la ciencia. En este sentido, en 2003 el gobierno británico llevó a cabo un análisis en profundidad de la colaboración entre la universidad y las empresas, proponiendo fórmulas para mejorar el apoyo público a dicha actividad de colaboración[89]. En la actualidad, en Reino Unido están en funcionamiento una serie de medidas destinadas a fomentar actividades de colaboración en innovación entre empresas y organizaciones de investigación, y entre empresas. En Alemania, una cantidad importante de los fondos públicos destinados a actividades de innovación se dedican a consorcios de investigación que engloben a empresas y organismos de investigación. Las políticas en España y Francia hacen también hincapié en la colaboración público-privada[90].

Los resultados obtenidos en este estudio muestran que los "spillovers" recibidos (flujos de información recibidos) y la capacidad de apropiación de los resultados de la innovación tienen un efecto positivo sobre la probabilidad de cooperar en actividades de innovación.

A pesar de la importancia de los "spillovers", en España se obtiene que el factor más importante para las empresas a la hora de decidir si cooperan o no en actividades de innovación es la existencia de costes y riesgos elevados vinculados con las actividades de innovación. Este resultado puede ser reflejo de la falta de inversión privada o la escasez de capital riesgo en la economía española.

Los resultados que se han obtenido implican que el fomento de este tipo de acuerdos de cooperación puede reforzar la innovación, y este fomento puede ser promovido por medidas de política económica.

[89] HM Treasury (2003).

[90] Ver Abramovsky et al. (2004), Acosta y Modrego (2001), Fier et al. (2006) y MNRT (2005).

A.5. Bibliografía

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