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S.S.D: SECS-P/02

Sources and modes of innovation: young companies *vs* mature incumbents

Tesi di Dottorato di Pellegrino Gabriele

Matricola: 3710487

Anno Accademico 2011/12

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Coordinatore: Ch.mo Prof. Campiglio Luigi

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Chapter I
Introduction

The role of technological change as major source of economic growth has intrigued economists for decades if not centuries. Among classical economists, John Stuart Mill (1848) can be credited as the first to indicate technological change as an important compensation factor of the decreasing returns of scale that hinder long-term economic growth. However, the author does not examine the causes and sources of this technological change, aspects that have remained unexplored for about one hundred and fifty years. In the neoclassical model of economic growth (Solow, 1956), in a framework characterised by perfect competition and decreasing productivity of factors, the rate of technological change is seen as one of the determinants of the equilibrium level of per-capita income and consequently as one of the factors causing the disparities between countries. Although the Solow model is unquestionably a seminal contribution in the growth theory literature, it presents two important limitations: the exogeneity of technological progress and the production under diminishing returns to factors.

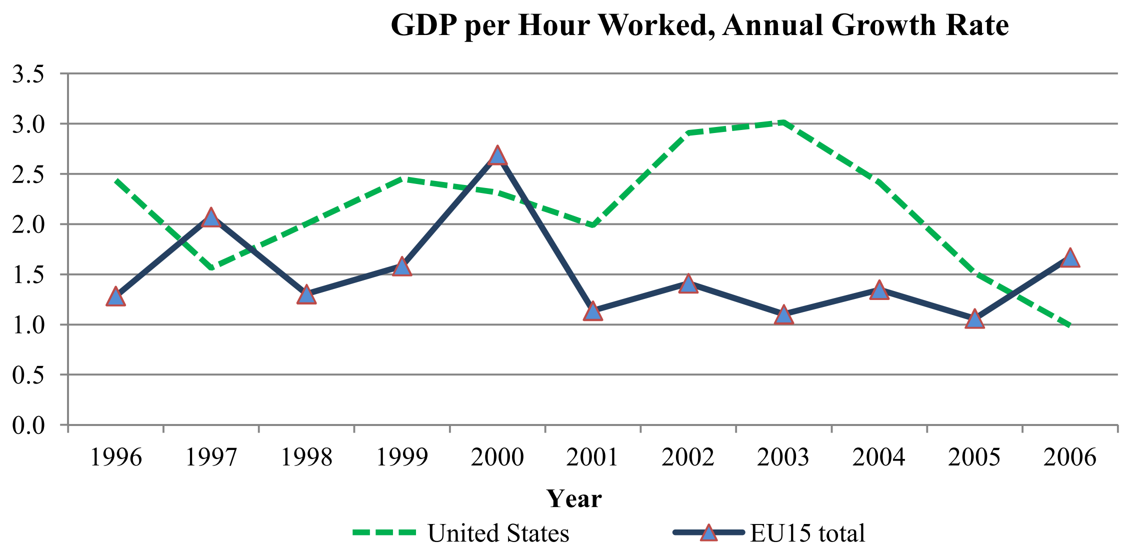
The endogenous growth models of the early nineties overcome the abovementioned shortcomings. Their main contribution is related to the fact that they consider technological change not as an exogenous factor to the economy, but instead as the result of purposeful actions: firms, in search of profitability, invest in knowledge (namely in R&D) and innovate, thereby generating technological progress. Accordingly, knowledge becomes an additional input factor of production that, unlike capital and labour, is not subject to the law of diminishing returns so promoting sustained growth (see Romer, 1991; Grossman and Helpman, 1991; Aghion and Howitt, 1992). Empirically, many studies have stressed the strong and long-standing relationship between R&D investment and output growth: in general, they show that a 1% increase in the R&D capital stock leads to a rise in output of between 0.05-0.1% (see Griliches 1992; Coe and Helpman 1995). Following these insights, a well-established empirical literature has been providing robust evidence on the fundamental role played by knowledge and R&D in boosting productivity. Generally, in this literature the overall elasticity of productivity with respect to R&D turns out to be positive and significant with a magnitude ranging from 0.05 to 0.25 depending on the data and the level of analysis (country, sector or firm).

Although the importance of R&D is unquestioned among scholars and policy makers, its relevance in terms of impact on economic and productivity growth has been proven to vary strongly across countries. In this respect, a long-standing debate has evolved about the divergence between the United States and the European Union in terms of both GDP and labour productivity growth. As clearly emerged from figure I.1, and as further suggested by numerous studies (see for example Blanchard, 2004), starting from the mid-90s the European Union has experienced a substantial deceleration in its historical catching up process to the United States in terms of labour productivity.

According to many authors, the main cause of this negative trend has to be ascribed to the R&D and innovation divide between the two continents (see Olinher and Sichel, 2000; Daveri, 2002). In this respect, over the last two decades European policy makers have been paying considerable attention in implementing measures aimed at increasing R&D investment. In particular, along with the "Lisbon agenda 2000" that sets an ambitious target for the European Union to become, by 2010, the most dynamic, competitive, knowledge-based economy in the world, a more recent and specific policy measure ("Barcelona target") consists of reaching an R&D/GDP level of 3%, two-thirds of which should come from the private sector (European Commission, 2002; European Council, 2002).

However, if on the one hand it is clear that the European Union considers the increasing in R&D investment as the main policy instrument for reducing the transatlantic productivity gap, on the other hand it still remains unclear how actually this goal can be reached. In other words, these particular policies do not specifically address the root causes of the innovative divide between the European Union and the United States.

Figure I.1: Labour Productivity Growth in the United States and the EU15: 1996–2006 (source: OECD).



Among several explanations put forward to account for this unexplored aspect, one of the most credited is the one that refers to a sectoral composition effect. More in detail the EU in comparison with the US, being more oriented towards medium-tech, rather than high-tech sectors appears to be also less R&D intensive. Specifically, EU has lost ground in particular in key information and communication technology sectors that have represented the most important drivers of United States growth in the 90s (see Moncada-Paterno-Castello *et al.*, 2009). According to this evidence, the EU' low R&D intensity can be considered more like a signal rather than a cause, with the real cause that has to be ascribed to the inappropriate industrial structure of the EU.

Recently, some authors have pointed to the fact that the US economy appears to be much more dynamic and able to stimulate the birth and growth of new firms that highly contribute to the renewal of the industrial structure, implementation of new technologies and economic growth. On the other hand young and new born firms in Europe are not able to play a significant role in the dynamics of the industry, with particular reference to the high-tech sectors (see Bartelsman *et al.*, 2004). Baumol *et al.* (2007), for instance, point out that, over the last 15 years, productivity growth in advanced economies has been due mainly to the development of innovative entrepreneurial companies, such as Microsoft, Intel, eBay, Amazon, Google and Apple among others.

Among these lines, Veuglers (2009) put forward an interesting conjecture according to which the EU's business R&D deficit with respect to the US can be almost totally accounted for by the former's lack of young leading innovators (or the so called yollies), that apart from being less in number are in addition much less R&D intensive.

Drawing data on the EU-1000 and non-EU-1000 highest R&D spenders contained in the 2008 edition of the EU Industrial R&D Investment Scoreboard, the author shows that EU-based yollies in comparison with their US counterparts play a much less relevant role in increasing R&D, sales and employment. More in detail, there appears that just 20% of leading innovators (defined by both market capitalisation and R&D expenditure) based in the EU are young (established after 1975), compared to 50% in the US. In addition, the EU yollies' share of the EU's total leading firms' R&D expenditure is just 7%, versus 35% in the US. Finally, it emerges quite clearly that the yollies located in the EU are much less R&D intensive than those located in the US. EU-based yollies have an R&D-to-sales ratio of 4.2% versus 10.2% for US yollies.

Although these evidence are quite relevant, they are based on analysis carried out on a specific cohort of firms and in particular on firms that are extremely successful, highly R&D intensive and remarkably large (10,000 employees on average). As a consequence these types of companies represent just a small portion of a country's industrial structure and have limited relevance in terms of policy implications. On the contrary, policy makers should focus on shaping measures aimed at facilitating and supporting the innovative activity of young and small firms in general in order to create the condition for the emergence of "innovative champions" like yollies. Accordingly, very recently, the European Commission has identified a new type of firms, the so called Young Innovative Companies (YICs). In detail, companies like these are defined as small, younger than a given age threshold (usually 6 or 8 years), innovative ('certified' by external experts on the basis of a business plan as capable of developing products or processes which are new or substantially improved) and operating in all sectors of the economy. Aware of the important role that these firms can play in fostering economic growth, many EU member States, in the few past years have been promoting policy intervention aimed at encouraging their establishment and their growth. In particular, great attention has been paid to lowering the barriers that new firms can face, such as access to early-stage risk financing (Schneider and Veugelers, 2010).

Despite the unquestionable relevance of this topic, proved by increasing policy attention, surprisingly, the scientific and academic community has shown scant interest in providing empirical support to the contribution of entrepreneurial companies to innovate performance in Europe. In this respect, very few studies have tried to analyse the link between firm's age and innovation, and in particular no evidence has been provided about the peculiarities of the innovative activity of young firms and its effectiveness. In this respect, there are a number of issues that remain unexplored and that could have an important impact in terms of policy implications. Bearing in mind the discussion so far, it would be reasonable to wonder about the factors that might lead a young firm to engage in R&D; or, if any particular differences exist between mature and young firms in terms of factors that affect the level of R&D investment.

The analysis of these relevant topics represents the core of the second chapter of this thesis, entitled **"On the relationship between R&D and firm's age"**. Drawing on an unbalanced dataset of more than 2,000 Spanish manufacturing firms observed over the period 1990-2008, the main aim and novelty of this work lies in the attempt to detect the existence of possible differences between firms of different ages in terms of the drivers that increase the probability of their engaging in R&D activity, on the one hand, and those that determine the intensity of this innovation, on the other. Moreover, taking advantage of the longitudinal nature of the dataset, we have tried to take into account the important role played by the previous R&D experience in determining the current firm's innovative choices. The results of the econometric estimations, obtained by using a recently proposed dynamic estimator, shed new light about the peculiarities of the innovative process of the young companies with particular reference to R&D activity. More precisely, it turns out that, if the past firms' innovative decision is an important R&D determinant in general, a lower degree of persistence is found in the innovative process carried out by the young firms, denoting a more erratic implementation of R&D projects of such firms. Moreover, the results indicate that different market and firms characteristics play a different role in boosting the innovation activity of firms of different ages. In particular, while market concentration and the degree of product diversification are found to be important in fostering the innovative activity of the mature firms only, young firms' spending on R&D appears to be more sensitive to demand pull variables, suggesting the presence of credit constraints.

According to the discussion so far, the second chapter of this thesis looks at the input side of firms' innovative activity. However, in order to have a more comprehensive and detailed picture of the firms' innovative process, it is necessary to look also at the output side of the innovation and more in detail at the link that exists between innovative input and innovative output. In particular, the study of this relationship explicitly emerges as one of the important components of those analyses whose main aim is to measure the returns of the innovation. The literature on this subject was initiated by Griliches (1979) that proposes a three equation model of technological change in which one of them is the so called Knowledge Production Function (KPF), a function designed to depict the link between a measure of innovative input (namely R&D) with a measure of innovative output (namely Patents). This seminal contribution has paved the way for the emergence of a field of research that has been gaining relevance in the last 30 years and whose main aim is to analyse the peculiarities of the innovative process and its contribution to economic growth.

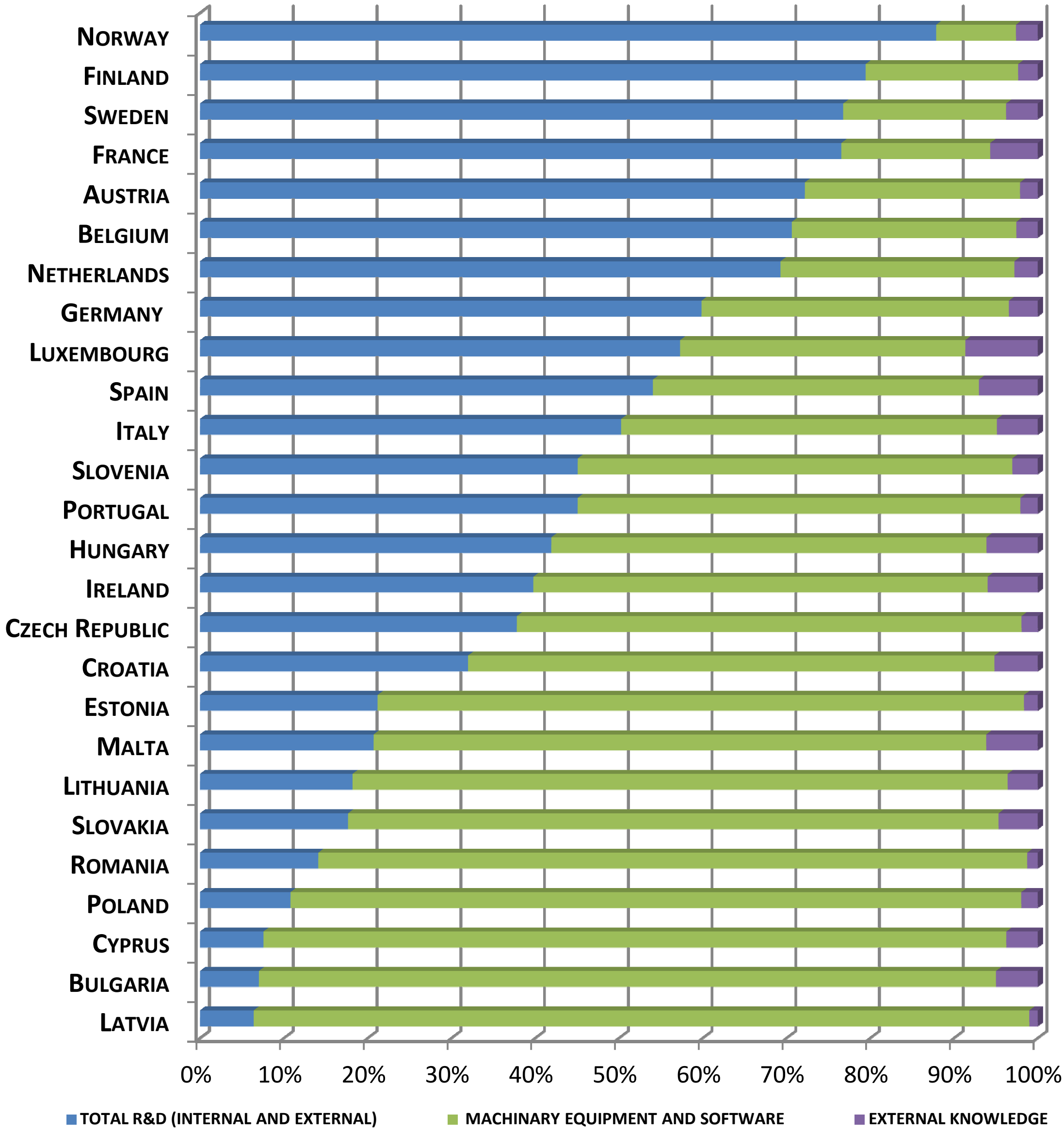
Due also to the design of standard statistics in innovation that has historically paid attention almost exclusively to R&D processes and patenting activity, most of the previous literature on the subject has confined its interest to the link between these two measures of innovation activity. However, such an approach appears to be too restrictive. In fact, although as previously mentioned, the importance of R&D activity is unquestionable, many of the firms' activities that lead to innovation do not reckon on this innovative input. In this respect as Dosi suggests, innovation has to be seen as the "search for, and the discovery, experimentation, development, imitation and adoption of new products, new production of processes and new organizational setups" (Dosi, 1988). It is hence quite obvious that along with formal R&D activities other important sources of innovation drive innovation output. One of the most relevant is represented by the acquisition of external technology that can take place by means of investment in new machineries and equipment (the so called "embodied technical change"), or through the purchasing of licenses, consultancies and know-how (the so called "disembodied technical change").

In this respect, it is worth noting that the relevance of this particular source of innovation was already highlighted in the early 60s. Indeed, Salter (1960) and subsequently Jorgenson (1966) theoretically discuss the embodied nature of technological progress and the effects related to its spread in the economy. Following this insight, starting from the 80s, some authors have put forward particular type of models, denominated Vintage Capital models, whose main aim was to describe a process according to which the replacement of old equipment represents the main way through which firms introduce process innovation (Freeman *et al.,* 1982; Freeman and Soete, 1987). More recently, the role of the embodied technological change has also been considered in the macroeconomic models of (endogenous) growth (Greenwood *et al.* 1997).

Clear support for the major contribution given by the acquisition of external technology in determining the innovative behaviour of firms is provided by aggregate figures. Figure I.2 shows the distribution of innovative expenditure among the 27 EU countries (excluding the UK), distinguishing among R&D (formal and informal), investment in machinery and equipment (embodied technological change) and purchasing of external disembodied technological change. As can be seen, the distribution of innovative effort among European countries appears to be quite heterogeneous. More in detail, the innovation activity of some countries (mostly located in Central and Northern Europe) is mainly driven by investment in R&D (both internal and external), while other member states (mostly Eastern and Mediterranean countries) rely almost exclusively on investment in machinery and equipment. This latter group of countries includes also Italy where, as many other Mediterranean countries, the core of the national industrial structure is represented by middle-tech and traditional sectors.

Apart from by the industrial and technological characteristics of a country, the relevant importance of the different sources of innovation will depend also upon the firm peculiarities. Among these, an important role can be surely played by firm age.

Figure I.2: Distribution of firms' innovative expenditures among the EU 27 Countries (source: Eurostat – Community Innovation Survey 2008).



In this respect, it is possible to think that young firms, due to their distinctiveness, differ from mature and incumbent firms in terms of their input-output relationship. According to the discussion presented so far, a better understanding of these relevant aspects, scarcely explored in the literature, is certainly worthwhile.

Chapter 3 and 4 aim to address this gap in the literature. More in detail, the first paper entitled **"Young firms and innovation: a microeconometric analysis",** provides some evidence regarding possible differences between young and mature innovative firms in terms of the factors that can affect the probability of introducing product innovation and the intensity of innovation. In doing so, using micro data stemming from the third wave of the Italian Community Innovation Survey (CIS) an extended knowledge production function approach is applied. In particular, apart from formal R&D, this work also takes into account the important role played by other sources of innovation with particular reference to technological acquisitions. The results of the estimations show that, although in-house R&D is linked to the propensity to introduce product innovation both in mature and young firms, innovation intensity in the group of young firms is mainly dependent on embodied technical change from external sources, while formal R&D does not play a significant role.

Chapter 4 entitled **"How do innovative inputs lead to different innovative outputs in young and mature firms?"** provides a more complete and structured framework for the research question analysed in the previous chapter. In this respect, it relies on two different sources of micro data, namely, the third and fourth wave of the Italian CIS. Using these two fully comparable cross-section datasets, this work investigates the determinants of two types of innovative inputs (R&D and technological acquisitions) and their relationship with two different innovative outputs (product and process innovation) for both mature and young firms. In doing so it relies on a nonlinear structural model made up of 6 different equations. The results of the estimations suggest that distinct firm and market characteristics play a distinct role in boosting different types of innovation activity for firms of different ages. More in detail, while international market exposure and the methods of appropriability are relevant for both innovative inputs, the cooperation in innovation activities appears to be important in increasing the level of investment in R&D but not in technological acquisition. Moreover, young firms show a higher level of sensitivity than their mature counterparts to the sources of information to innovation with respect to the magnitude of their innovative effort. On the contrary factors like methods of appropriability and support to innovation appear to be more important in enhancing the level of investment in both R&D and technological acquisitions, for the mature firms only. Finally, the two innovative inputs appear to be equally important in determining both innovative outputs for the two sub-samples of firms.

As emerged from the discussion above, the core of this work is structured in three different chapters. Although they are strictly linked and have to be considered as part of a common research project, each of them can be read independently. The framework of each is as follow.

Firstly, the subject, the motivation and the main contribution of the study with respect to the existing literature are presented. Secondly, a careful discussion of the theoretical approach to the topic is provided along with a comprehensive description of the dataset used for the empirical analysis. Thirdly, a detailed outline of the econometric methodologies used for the estimations is given and finally the main conclusions and some policy suggestions are provided.

Lastly, the fifth chapter provides a general overview of the three previous chapters, outlines the main conclusions of the entire work and offers some policy implications derived from the empirical results.

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Chapter II
On the relationship between R&D and firm's age

2.1 Introduction

The analysis of the determinants of a firm's R&D activity is a classic concern of the *Economics of Innovation*, dating from the seminal contribution by Griliches (1979) (see also Griliches, 1994 and 1996). More recently, endogenous growth models have singled out human capital and its accumulation through education and knowledge as the main sources of long-term economic growth (see Mankiw *et al.*, 1992; Romer, 1994; Lucas, 2002). In this respect, several studies state that R&D investment represents the main engine of technological progress and economic growth (see Nelson and Winter, 1982; Mansfield, 1988; Aghion and Howitt, 1998).

Interest in the field has been reawakened following recent reports that identify the essential role played by a specific type of firm – the so-called Young Innovative Companies (YICs)[1] – in the renewal of the industrial structure and in contributing to aggregate economic growth. Baumol *et al.* (2007), for instance, point out that, over the last 15 years, productivity growth in advanced economies has been due in the main to

[1] According to the European Commission's State Aid rules, Young Innovative Companies are defined as small companies, less than six years old, 'certified' by external experts on the basis of a business plan as capable of developing products or processes which are new or substantially improved and which carry a risk of technological or commercial failure, or have R&D intensity of at least 15% in the last three years or current year (for start-ups).
However, some European countries in adopting the European Directive have extended the age threshold (i.e. 8 years for France and Estonia).

the development of innovative entrepreneurial companies, such as Microsoft, Intel, eBay, Amazon, Google, Apple, among others.

In seeking to account for the persistent gap that exists between the EU and the US in terms of innovative performance and productivity, scholars and policy makers often refer to weaknesses regarding YICs. Indeed, in Europe, young companies have lower capacities to innovate and higher rates of early failure (see Bartelsman *et al.*, 2004; Santarelli and Vivarelli, 2007), whereas the US economy has been able to generate a steadily increasing flow of YICs that not only survive but which develop new products at the core of emerging sectors. For these reasons, many EU countries have implemented policies to support the creation and growth of YICs, focusing - for instance - on facilitating their access to funding and providing support for the commercialization of innovation (see EC-DG ENTER, 2009; Schneider and Veugelers, 2010).

Despite this policy concern, few studies have explicitly examined the specific characteristics of YICs and their contribution to Europe's innovative performance. Moreover, little evidence has been gathered on a number of important issues that could have major policy implications. What, for example, are the factors that might lead a young firm to engage in R&D? Are there substantial differences in the factors that affect the level of R&D investment in YICs, on the one hand, and mature firms, on the other? Is the R&D process equally persistent in firms of different ages?

By drawing on a large longitudinal dataset of Spanish manufacturing firms, the objective of this paper - and its main novelty - lies in the assessment we make of the differences that exist between firms of different ages in terms of the drivers that increase the probability of their engaging in R&D activity, on the one hand, and those that determine the intensity of this activity, on the other. A recently proposed dynamic type-2 tobit model (Raymond *et al.*, 2010) is applied to perform the microeconometric analysis.

The remainder of the paper is organised as follows. Section 2 provides a brief review of previous studies on the determinants of R&D. In Section 3 we present the hypotheses that will be tested. Section 4 provides a discussion of the econometric methodology adopted. In Section 5 we present the data and the variables used in the empirical analysis. The estimation results are discussed in Section 6, while in Section 7 the main conclusions and findings of the study are briefly summarised.

2.2 The literature

The first author to conduct a theoretical analysis of the drivers of R&D activities was Joseph Schumpeter. In "Capitalism, Socialism and Democracy" (Schumpeter, 1942), the Austrian scholar claims: 'The atomistic firm operating in a competitive market may be a perfectly suitable vehicle for static resource allocation, but the large firm operating in a concentrated market is the most powerful engine of progress and … long-run expansion of total output'. This simple statement has inspired a vast and well-established body of literature, both theoretical and empirical, which has – with some exceptions – confirmed Schumpeter's predictions (the so-called "Schumpeterian hypothesis") that the size of the company and the degree of market concentration are direct determinants of innovation activity. In this line, several studies note, firstly, that larger firms are more likely to undertake R&D activity as they are not affected by liquidity constraints (i.e. they enjoy easier access to external finance and larger internal funds; see Cohen and Klepper, 1996; Mairesse and Mohnen, 2002; Conte and Vivarelli, 2005); secondly, that firms with greater market power have greater incentives to innovate because they can better appropriate returns from their R&D investments (see Gilbert and Newbery, 1982; Blundell *et al.*, 1999).

A further important stream of literature related to the drivers of innovation activity is represented by the demand-pull *vs* technology-push debate. Since Schmookler's (1962) seminal contribution, many authors have tested the hypothesis that demand drives the rate and direction of innovation. In this line, various theoretical and empirical approaches, both at the aggregate (see Schmookler, 1966; Scherer 1982; Kleinknecht and Verspagen, 1990; Geroski and Walters, 1995) and at the microeconomic level (see Brouwer and Kleinknecht, 1996, 1999; Piva and Vivarelli, 2007) converged to consider demand and market growth as essential factors for boosting innovation activity based on increasing returns of scale, optimistic expectations and diminishing cash constraints.

The first comprehensive discussion of the technology-push hypothesis was put forward by Mowery and Rosenberg (1979). The core idea is that the rate and direction of technological change is basically affected by advances in science and technology and by the availability of exploitable 'technological opportunities' (see Klevorick *et al*., 1995). Subsequent studies extended this notion stressing the key role to be played by cumulated knowledge investment in fostering firms' 'absorptive capacity', that is their ability to exploit external technological opportunities (see Mowery, 1983; Pavitt, 1984; Cohen and Levinthal, 1989 and 1990; Rosenberg, 1990; Rosenberg, 1994).

In essence, the technology-push theory holds that R&D activities are dependent on their own rules of development. Thus, within a firm, R&D activities are highly localized (Atkinson and Stiglitz, 1969) and path-dependent (see Rosenberg, 1982; David, 1985). Closely related to these concepts, is the idea of a dominant 'technological trajectory' according to which innovation, and in particular R&D activities, are processes that show high degrees of cumulativeness and irreversibility and, as a result, are characterised by a higher level of persistence (see Dosi, 1988). These considerations open up the way to a dynamic first order autoregressive [AR(1)] specification of firms' decisions regarding both whether or not to engage in R&D and how much to invest in R&D activities.

However, as Dosi (1988 and 1997) points out, patterns of technical change are the result of the interaction between different types of market incentives, on the one hand, and technological opportunities, on the other. Working within this framework, most recent empirical studies tend to take both demand-pull and technology-push theories into account (see Crépon *et al*., 1998, Mohnen and Dagenais, 2002).

Moreover, in order to provide a more realistic and comprehensive analysis of a firm's innovation process, the specific features of a given company needs to be considered. Thus, thanks in part to the availability of more detailed innovation surveys, in recent years various authors have reported more accurate empirical analyses, providing vital evidence about the role that endogenous firm characteristics may have in stimulating/hindering R&D activities. The remainder of this section undertakes a brief discussion of the main results emerging from this more recent strand of literature.

For instance, many recent studies have devoted their attention to the analysis of the impact of R&D subsidies. Most of them (see for example Callejon and García-Quevedo, 2005; González *et al.,* 2005 for the Spanish case) have provided empirical evidence that is moderately supportive of the positive effect of government subsidies in stimulating R&D activities. However, some contributors (see, for example, Wallsten, 2000) have questioned these results on the grounds that very few studies explicitly consider the potential endogeneity of public funding.

Reverse causation has also been detected in the relationship between R&D and exports. Specifically, two different mechanisms can characterise this relationship. On the one hand, there is the possibility of 'learning by exporting': exporters, through interaction with foreign agents, can exploit knowledge inputs not available to domestic firms, enhance their competences and consequently be more likely to invest in R&D activities (see Melitz, 2003; Yeaple, 2005; Cassiman *et al.*, 2010). On the other hand, some authors (see, for example, Clerides *et al.*, 1998) have highlighted the possibility of the emergence of a self-selection mechanism: most innovative firms are more likely to penetrate foreign markets and self-select themselves so as to engage in tougher foreign competition. Given these two quite distinct explanations, an analytical framework is required to properly deal with this endogeneity issue.

A further firm characteristic that has been demonstrated to have a positive effect on the propensity of a firm to engage in R&D is its degree of product diversification. Here, economic theory notes a close relationship between scope economies and R&D activity: a firm with a diversified portfolio of products can benefit from potential internal knowledge spillovers and so be better positioned to understand the applicability of new ideas (Henderson and Cockburn, 1996).

Piva and Vivarelli (2009) claim that higher manpower skills may also result in higher levels of R&D investment. Indeed, skilled workers, in comparison with their unskilled counterparts, are: 1) more suited to dealing with complexity - a prominent characteristic of innovation (Song *et al.*, 2003); 2) more likely to 'absorb' knowledge and consequently to reinforce the absorptive capacity of a given organization (Cohen and Levinthal, 1990); 3) more successful in exploiting innovative ideas.

2.3 Hypotheses to be tested

As discussed in the introduction, the purpose of this paper is to identify any differences that might exist between young and mature firms in terms of the factors that stimulate the probability of their engaging in R&D activity and those that determine the intensity of this investment. Specifically, and bearing in mind the discussion presented in the previous section, we propose the following two research questions:

- Do YICs show the same degree of sensitivity to certain drivers as that shown by their mature counterparts, when deciding whether to engage in R&D activities and when choosing how intensively they wish to invest in R&D?

- Furthermore, is innovation in YICs less persistent than it is in their mature counterparts?

It is not an easy task to identify specific theoretical predictions concerning these questions. Indeed, to the best of our knowledge, no previous studies have examined the R&D drivers in YICs, although there is some evidence of the role of a firm's age in determining the decision to engage in R&D activities and in enhancing its investment in R&D.[2] However, some hypotheses can be derived from the related streams of literature discussed in the previous section.

An initial source of the differences manifested by firms of different ages might well be related to the impact that financial and liquidity constraints have in determining a firm's

[2] A positive relationship between a firm's age and the probability of engaging in R&D is found in both Artés (2009) and Ortega-Argilés et al. (2005) for the Spanish case.

decision to engage in R&D. Clearly, a lack of finance is a major hindrance to innovation and investment in R&D activities. In this regard, there is a vast body of empirical literature highlighting the relative advantage enjoyed by large firms (Beck and Demirgüç-Kunt, 2006; Czarnitzki, 2006). Hall (2008), for example, suggests that small firms are more likely to be affected by imperfections in capital markets than are large firms, since the former can rely less on internal funds.

By contrast, less attention has been given to the differences - in terms of financial constraints affecting the investment in R&D - between mature and young firms (Cincera, 2003; Czarnitzki and Hottenrott, 2011). Yet, there are various reasons why YICs should be more sensitive to such constraints than are their mature counterparts. Firstly, young firms typically have yet to develop a reputation and their sources of collateral are scarce - two factors that are important in mitigating capital market imperfections. Secondly, they can rely less on internal funds since accumulated past profits are scarce by definition[3]. Here, for example, Fluck *et al.* (1997) report that the ratio of external finance to total finance tends to fall once a firm has been operating for more than seven or eight years, while Reid (2003) provides evidence of an inverse relationship between a firm's age and its debt ratio. Thirdly, in contrast with mature firms, newly founded entities do not have recourse to an established, long-term relationship with banks (Petersen and Rajan, 1995; Martinelli, 1997; Berger and Udell, 2002). By the same token, as Fritsch *et al.* (2006) point out, bank financing of the R&D projects of young firms might be more limited given the higher risks of default. Finally, established companies can base their innovative activity on past successes, concentrating their attention - for example - on product differentiation or improvement, whilst YICs might be forced to undertake more fundamental R&D investments which may prove to be more costly and uncertain.

The above discussion points to a negative relationship between a firm's age and liquidity constraints, suggesting that young firms should be more sensitive than their

[3] Note that mergers and acquisitions are excluded from the definition of YICs.

mature counterparts to some R&D drivers. More specifically, the following hypotheses can be drawn:

H1: Since YICs may be affected by liquidity constraints and possible credit rationing, they attach greater importance than do their mature counterparts to current sales and internal cash flow when deciding to invest in R&D activities.[4]

H2: Since exports are a key component of demand evolution, YICs should show higher innovation/export elasticity.

H3: Similarly, YICs should be more sensitive to the amount of subsidies received as these represent an alternative source for financing their R&D projects.

A further characteristic that can play a role in differentiating mature from young firms is obviously their degree of experience. An essential part of this experience is represented by the learning process (Arrow, 1962). However, this concept can be considered more broadly and, in particular, as a cumulative improvement in the stock of knowledge within a given firm. Thus, experience and the learning process can be essential in increasing a firm's innovative capability and absorptive capacity over time: learning in one period will render more efficient the process of accumulation of knowledge in the subsequent period. By definition, this path-dependent pattern should be more obvious in mature, well-established firms than in inexperienced YICs. Thus, we can put forward the following hypothesis:

H4: Given their relative inexperience, the innovative processes of YICs should follow a more erratic path and be less persistent[5].

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[4] Evidence of the greater importance of current sales in determining the innovation decision of financially constrained firms can be found in Goodacre and Tonks (1995), Hall *et al.* (1999), O'Sullivan (2005) and Piva and Vivarelli (2007).

[5] This hypothesis has to be considered reasonable in average. Indeed, sectoral differences can alleviate or amplify this degree of persistence (i.e. innovative process more persistent in high-tech sectors than in the low tech ones).

A firm’s experience and capacity to absorb knowledge are also important in determining the magnitude of the impact on a firm’s innovation activity through the exploitation of economies of scope:

H5: Well-established firms, being characterized by a larger scale and greater experience and absorptive capacity, are in a better position to take advantage of economies of scope. Accordingly, product diversification is expected to be a more important R&D driver for mature innovative firms than for YICs.

In line with the arguments presented above, the availability of advanced skills is one of the main ways in which a young firm can compensate for its lack of experience and its limited absorptive capacity; therefore:

H6: Given their lower level of experience and absorptive capacity, YICs should be more dependent on their own skill endowment as an internal driver of R&D investment.

Finally, appropriability conditions can be expected to be much more relevant R&D drivers for mature, larger incumbents than they are for young, small newcomers (see Acs and Audretsch, 1988 and 1990; Audretsch, 1997). Hence, the following hypothesis can be forwarded:

H7: The degree of market concentration should be more important in stimulating the innovation activity of mature firms than in stimulating that of their younger counterparts.

2.4 Econometric methodology

Following Artés’ (2009) approach, we model an R&D firm’s decision-making process by distinguishing between long- and short-run strategies. Specifically, we assume that the long-run, or strategic choice involves deciding whether to engage in R&D activity or not, while the short-run decision concerns how much to invest in R&D. Formally, we have:

$$d_{it} = 1\left[\rho d_{i,t-1} + \delta' Z_{it} + \alpha_{1i} + \varepsilon_{1it} > 0\right] \tag{1}$$

$$\gamma_{it} = \begin{cases} \partial\gamma_{i,t-1} + \beta' X_{it} + \alpha_{2i} + \varepsilon_{2it} & if\ d_{it} = 1 \\ 0 & if\ d_{it} = 0 \end{cases} \tag{2}$$

Equation (1) is the selection equation and it models the long-run decision of enterprise i to invest in R&D activities as a latent function of its past R&D decision ($d_{i,t-1}$), strictly exogenous explanatory variables (Z_{it}), time-invariant unobserved individual effects (α_{1i}) and an idiosyncratic error term (ε_{1it}). If the incentive to invest in R&D (expression in brackets) is larger than zero, firms *i* can be defined as innovative.

The main equation (2) models the short-run decision of innovator i (conditional on: $d_{it} = 1$) as a function of its past R&D investments ($\gamma_{i,t-1}$), its characteristics (X_{it}), time-invariant unobserved individual effects (α_{2i}) and an idiosyncratic error term (ε_{2it}) independent of X_{it}.

The dynamic nature of these two equations, together with the fact that equation (2) can only be observed for those firms that invest in R&D activities, leads us to employ an econometric methodology based on the application of a dynamic type-2 tobit model.

To estimate such a model, we must first solve two problems, namely: 1) the presence of unobserved individual effects; 2) the correlation between the initial conditions and the individual effects. The latter problem occurs because the first observation for each firm referring to a dynamic variable (initial condition) is determined by the same data generation process, and so it turns out to be correlated with both the individual error term and the future realizations of the variable.

In order to deal jointly with these problems, we use the methodology proposed by Raymond *et al.* (2010). First, we assume the individual error terms, α_{1i} and α_{2i}, have a joint distribution and we apply a random-effects approach. Second, we treat the initial conditions problem in line with Wooldridge (2005), and assume that the unobserved individual effects depend on the initial conditions and the strictly exogenous variables:

$$\alpha_{1i} = b_1^0 + b_1^1 d_{i0} + b_1'^2 Z_i + u_{1i} \tag{3}$$

$$\alpha_{2i} = b_2^0 + b_2^1 \gamma_{i0} + b_2'^2 X_i + u_{2i} \tag{4}$$

where b_1^0 and b_2^0 are constants, d_{i0} and γ_{i0} are the initial values of the dependent variables and Z_i and X_i are Mundlak within-means (1978) of Z_{it} and X_{it}. The vectors $(\varepsilon_{1it}, \varepsilon_{2it})$ and (u_{1i}, u_{2i}) are assumed to be independently and identically (over time and across individuals) normally distributed with means 0 and covariance matrices, equal to:

$$\Omega_{\varepsilon 1 \varepsilon 2} = \begin{pmatrix} 1 & \rho_{\varepsilon_1 \varepsilon_2} \sigma_{\varepsilon_2} \\ \rho_{\varepsilon_1 \varepsilon_2} \sigma_{\varepsilon_2} & \sigma_{\varepsilon_2}^2 \end{pmatrix} \text{ and } \Omega_{u1u2} = \begin{pmatrix} \sigma_{u_1}^2 & \rho_{u_1 u_2} \sigma_{u_1} \sigma_{u_2} \\ \rho_{u_1 u_2} \sigma_{u_1} \sigma_{u_2} & \sigma_{u_2}^2 \end{pmatrix}$$

Hence, the likelihood function of a given firm *i*, starting from t=1 and conditional on the regressors and the initial conditions, can be written as:

$$L_i = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \prod_{t=1}^{T} L_{it} \left(d_{it}, \gamma_{it} | d_{i0}, d_{i,t-1}, Z_i, \gamma_{i0}, \gamma_{i,t-1}, \mathrm{X}_i, u_{1i}, u_{2i} \right) g(u_{1i}, u_{2i}) du_{1i}\, du_{2i} \tag{5}$$

where $\prod_{t=1}^{T} L_{it} \left(d_{it}, \gamma_{it} | d_{i0}, d_{i,t-1}, Z_i, \gamma_{i0}, \gamma_{i,t-1}, \mathrm{X}_i, u_{1i}, u_{2i} \right)$ represents the likelihood function once the individual effects have been integrated out and can be treated as fixed, and $g(u_{1i}, u_{2i})$ is the bivariate normal density function of $(u_{1i}, u_{2i})'$.

Therefore, equations (1) and (2) are jointly estimated by using the maximum likelihood estimator and are correlated through the individual effects ($\rho_{u_1 u_2} \neq 0$) and the idiosyncratic error terms ($\rho_{\varepsilon_1 \varepsilon_2} \neq 0$). The 'total' correlation between the two equations[6] being:

$$\rho_{\text{tot}} = \frac{\rho_{u_1 u_2}\sigma_{u_1}\sigma_{u_2} + \rho_{\varepsilon_1 \varepsilon_2}\sigma_{\varepsilon_2}}{\sqrt{\left(\sigma_{u_1}^2 + 1\right)\left(\sigma_{u_2}^2 + \sigma_{\varepsilon_2}^2\right)}} \qquad (6)$$

2.5. Dataset and variables

The data used in this work are drawn from the Survey on Business Strategies (*Encuesta Sobre Estrategias Empresariales*, henceforth ESEE) which has been conducted yearly since 1990 by the SEPI foundation (formerly the *Fundacíon Empresa Pública*), on behalf of the Spanish Ministry of Industry. The annual survey comprises extensive information on around 2,000 companies, with a particular focus on technological activity and the main characteristics of the market in which each firm operates.[7] The sampling procedure ensures representativeness for each two-digit NACE manufacturing sector, following both exhaustive and random sampling criteria. Specifically, in the first year of the survey all Spanish manufacturing firms with more than 200 employees were required to participate (715 in 1990), and a sample of firms employing between 10 and 200 workers were selected using a stratified, proportional, restricted and systematic sampling method with a random start (1,473 firms in 1990). In order to guarantee a high level of representativeness and to preserve the inference properties, newly created

[6] The lower panel of Table 6 reports the estimates of the extra parameters included in (6).

[7] For a more detailed description of the database see http://www.funep.es/esee/en/einfo_contiene.asp.

companies have been incorporated in the survey every year according to the same criteria. In this way, both the sample of respondent firms with fewer than 200 workers and more than 10 (rate of response around 4%) and the sample of respondent firms employing more than 200 workers (rate of response around 60%) are representative of Spanish industry.[8]

In this study, we consider survey data for the period 1990 to 2008. The original sample comprised 34,849 observations, but because of missing variables and the fact that some firms underwent mergers and acquisitions,[9] we ended up with an unbalanced panel of 21,706 observations. Table 2.1 shows the composition of this unbalanced panel according to the number of years a given firm is observed. As can be seen, around 59% of the 3,489 firms included in the final sample were observed for fewer than seven years. The remaining 41% were observed for at least seven years and a far from negligible percentage (around 25%) were observed for more than ten years.

< INSERT TABLE 2.1 >

Given the specific aim of this study, we needed to establish an age threshold so as to divide the full sample into young and mature firms. We opted for eight years, in order to obtain a good degree of representativeness in the sub-sample of young firms, albeit without increasing the age threshold too far.[10] Table 2.2 shows the size of the two sub-samples of mature and young companies, according to their innovative status. As can be seen, about 33% of the total sample of firms engage in R&D (both internal and external), whereas only 21% of the 1,168 firms aged eight years or less engage in R&D activities. Hence, the proportion of R&D performers increases with the age of the firm.

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[8] Several studies provide evidence of the representativeness of ESEE for Spanish industry (see, among others, González *et al*., 2005; Lopez, 2008).

[9] These firms were eliminated from the sample in the years following the merger or acquisition.

[10] Robustness checks were performed assuming alternative thresholds of nine and ten years. Our results – available upon request – are consistent (both in terms of the sign and statistical significance of the estimated coefficients) with those discussed in Section 6. In contrast, convergence problems prevented us from running robustness checks for thresholds lower than eight years, because of the paucity of observations within the sub-sample of young firms.

< INSERT TABLE 2.2 >

Table 2.3 shows the transition probabilities of engaging in R&D activities or otherwise during the period analysed, distinguishing between mature and young firms. Unsurprisingly, innovation is highly persistent, while transitions are very rare. Nearly 88% of R&D performers in one period persisted in this activity during the following year, with just 12% interrupting their innovative activities. By the same token, roughly 94% of non R&D performers maintained this status into the subsequent period while just 6% initiated innovation activities. Interestingly, less persistence is observed in the sub-sample of young firms; in fact, only 81% of young R&D performers in one period maintained this status into the next period. This evidence is in line with our hypotheses (H4) and calls for a more detail analyses.

< INSERT TABLE 2.3 >

2.5.1 Variables

In line with the econometric methodology described in Section 4, two dependent variables are considered for the dynamic equations: a dummy variable that takes a value of 1 if R&D expenditures (both internal and external) are greater than 0 is used in equation (1); and the natural logarithm of R&D expenditures as a measure of a firm's innovative effort is used in equation (2). The covariates are then selected according to the theoretical discussion advanced in Section 2 and the seven hypotheses proposed in Section 3.

The rationale underlying the strategy adopted in differentiating between the two estimated equations is linked to the time horizon of the firm's R&D decisions.[11] In other

[11] The decision to distinguish between the two equations was undertaken exclusively on theoretical grounds. In fact, given that the econometric methodology used here is based on a fully parametric approach, there are no exclusion restrictions in the vectors of what are strictly exogenous explanatory variables. This means that Z_{it} in equation (1) and X_{it} in equation (2) may be the same, completely different or they may have common explanatory variables (see Raymond *et al.*, 2010).

words, it is plausible that some factors are only important in determining a firm's long-run decision (equation 1), while others are relevant in both cases (equations 1 and 2).

In the case of those factors that only affect a firm's decision as to whether or not to engage in R&D, we have introduced two dummy variables: the 'CONC' variable that indicates whether a firm operates in a highly concentrated market (with fewer than 10 competitors); the 'DIVER' variable which identifies firms with greater product diversification. Our decision to include these variables in the selection equation only is based on their discrete nature and on the fact that they depict firm or market characteristics which are highly persistent over time. Therefore, it is plausible to think that these structural features may affect a firm's long-run decision to undertake R&D activities or not.

In the case of the regressors that are included in both equations, we first sought to verify the demand-pull hypotheses H1, H2 and H3 by considering a dummy variable, 'DYNAM'[12] - that takes a value of 1 if the main market in which the firm operates is expansive - and two continuous variables: 'LEXP_1'and 'LSUB_1' that record, respectively, the value of the firms' exports and the total amount of subsidies received by the firms (both in logs). In order to avoid possible problems of endogeneity, we have considered the one period lagged value of both the continuous variables.[13]

A further factor that might prove to be important in determining both decisions is represented by the 'SKILL' variable (see hypothesis H6). This measures the proportion of skilled employees (engineers and graduates) within a firm.

Finally, the log of employees is included in both equations, in order to control for firm size ("Schumpeterian hypothesis").

[12] In principle, it would have been better to consider a continuous variable measuring a firm's total sales; however, to avoid multicollinearity due to the high correlation between this variable and the LEXP_1 variable (ρ=0.75), we opted in favour of a dummy variable.

[13] In fact, as discussed in Section 2, it may well be the case that innovative firms are more likely to receive public subsidies and to enter foreign markets.

Table A2.1 in the Appendix describes the variables used in the empirical analyses, while Table 2.4 reports the corresponding descriptive statistics, distinguishing between the total sample, mature and young firms.[14]

< INSERT TABLE 2.4>

Table 2.5 shows sectoral composition and firm's average size of the total sample and distinguishes between young and mature firms. As can be seen, no striking sectoral differences emerge; however, to control for any particular industry-specific market and technological factors that might affect a firm's propensity to engage in R&D activities, a set of industry dummies was included in all the regressions (19 two-digit dummies).

As expected, young firms are systematically smaller than their mature counterparts (on average 103 *vs* 228 employees). This confirms that firms' size increase with age. As mentioned above, in order to ensure that the results of the analysis are not affected by any potential scale effect, we included in both equations the 'LEMP' variable, which measures the logarithm of the total number of employees in a firm.

Finally, all the estimates were checked for time dummies, in order to take into account possible macroeconomic and cyclical effects.

< INSERT TABLE 2.5 >

[14] As can be seen, for most the explanatory variables the between variation (across firms) is much higher than the within variation (time variation). This trait, which is very common in firm-level datasets, means the variables are strongly correlated with their Mundlak or within means (see Table A2 in the Appendix). Thus, to avoid problems of multicollinearity between the variables and their within means (which might bias the results of the main estimations), we followed the strategy adopted by Raymond *et al.* (2010, FN 8, p. 500) and we assumed the individual error terms to be correlated only with the initial values of d_{it} and y_{it}.

2.6 Results

Table 2.6 reports the econometric results of the dynamic panel data type-2 tobit model applied to the whole sample and independently to the two sub-samples of mature and young firms. Specifically, the top part of the table shows the estimates of the equation (1) parameters; the middle section of the table shows the estimation results of the equation (2) parameters; while the bottom section reports the coefficients of the initial conditions (d_{i0}, y_{i0}), the cross-equation correlations ($\rho_{u_1 u_2}$, $\rho_{\varepsilon_1 \varepsilon_2}$) and the standard deviations of the error terms (σ_{u_1} , σ_{u_2}, σ_{ε_2}).

< INSERT TABLE 2.6 >

As can be seen from the bottom section of Table 2.6, the initial conditions are highly relevant and the two equations are highly correlated via the individual effects and the cross-equation correlation.[15] Furthermore, the high level of significance of the coefficients of σ_{u1} and σ_{u2} indicates the need to take the unobserved heterogeneity into account. On the whole, these evidences support the adoption of the dynamic type-2 tobit model.

The first obvious result is the occurrence of persistence in innovation activity. As can be seen, the coefficients of the two lagged dependent variables are positive and highly significant in both equations and in all three models. This means that - even after controlling for individual unobserved heterogeneity, sectoral belonging and firm's characteristics - past innovative behaviour strongly affects both the current probability of engaging in R&D activity and the current level of R&D investment. However, both coefficients are smaller (by about 20%) for the young firms and these differences turn out to be highly significant in both the equations (see the last column of Table 2.6). According to our hypothesis 4 (see Section 3), this outcome suggests that, owing to their lack of experience, young firms are less persistent in their innovative behaviour

[15] The total cross-equation correlation (see eq. 6) is 0.23 for the full sample model, 0.25 for the mature firms and 0.25 for the young firms.

and that their innovative processes follow a more erratic path than that taken by their mature counterparts.

Apart from past innovative behaviour, other firm and market characteristics are found to be important R&D drivers.

Firstly, we turn our attention to the demand-pull theory. Indeed, the sign and significance of the DYNAM dummy variable suggest that favourable, expansive demand conditions are important factors both in increasing the probability of firms becoming R&D performers and in increasing the amount of their innovative investment. This holds true for both mature and young firms. However, as can be seen, the coefficients are larger in the case of young firms, although – in this case – the differences are not statistically significant. This result weakly corroborates our hypothesis 1, according to which newly created firms - due to their problems of liquidity constraints and credit rationing - are more sensitive to market prospects than their mature counterparts when deciding whether to engage in R&D and how much to invest.

This line of reasoning also applies to the outcome concerning the LEXP_1 variable: while in the selection equation its positive impact is obvious both for the mature and young firms; in the main equation its role is still positive and highly significant for the YICs, but appears not so relevant in the case of the mature firms[16]. Bearing in mind our hypothesis 2, this result can be seen as evidence -that the level of exports - representing a fundamental component of demand evolution - plays an essential role in fuelling the innovation activity of firms that are more liquidity constrained, as is the case of theYICs.[17]

[16] Although still positive, the coefficient is much lower and barely significant in the case of the mature firms; moreover, the difference between the estimated coefficient for the YICs and that for the mature firms is significant at the 99% level of confidence.

[17] This result is consistent with the outcome from a previous study (Pellegrino *et al.*, 2011), indicating that exporting YICs are more likely to perform better in terms of innovative intensity.

Conversely, a result that contrasts with expectations is our finding that young firms do not appear to be any more responsive to the amount of public subsidies received when determining how much to invest in R&D activities. Although subsidies are associated with a higher probability of firms becoming R&D performers in all three samples, the level of R&D investment among young firms is not significantly affected by the amount of subsidies they receive in the previous period. These results, which run contrary to hypothesis 3, seem to suggest the need to design different policy measures to support the innovative activity of different cohorts of firms (*i.e.* young *vs* mature).

Turning our attention to the remaining results, the CONC variable appears to increases the probability of engaging in R&D activities, but this relationship is statistically significant for the mature firms only. This is in line with our hypothesis 7 and confirms that only well established firms can take full advantage of market appropriability conditions.

A further result that is in line with expectations (H5) is our finding that the DIVER regressor significantly increases a firm's probability of engaging in R&D only with reference to the mature firms. This outcome suggests that mature firms, thanks to their larger scale and greater experience, are more able to exploit the innovative benefits derived from scope economies.

Firms with more high-skilled workers are more likely both to engage in R&D activities and to increase their amount of R&D investment. Interestingly enough, the results from the main equation support the proposed hypothesis 6, according to which YICs are expected to be more dependent on their own skill endowment[18].

Finally, the "Schumpeterian hypothesis" turns out to be significantly and homogeneously confirmed by our empirical analysis: larger firms are more likely both to engage in R&D activities and to invest more in R&D, and this is true both for the mature companies and for the YICs.

[18] In fact, the correspondent coefficient for the YICs is significantly larger than the one associated to their mature counterparts (see the last column of Table 6).

2.7 Conclusions

This paper has examined the determinants of R&D activities using a large, representative sample of both young and mature Spanish manufacturing firms for the period 1990 to 2008. The econometric analysis conducted has used a recently proposed dynamic type-2 tobit model, jointly accounting for both individual effects and endogeneity and handling the initial condition and sample selection problems.

Importantly, both engagement in and the amount of investment in R&D present a very high degree of persistence over time. However, a lower degree of persistence is found in the innovative processes carried out within YICs. This could reflect the relative inexperience of such firms, resulting in a more erratic implementation of R&D projects.

Moreover, accordingly with our hypotheses, we found that market concentration and product diversification appear to increase the probability of engagement in R&D only in the case of the mature firms. By contrast, YICs are found to be more sensitive to 'demand-pull' factors, such as expansionary demand conditions and the amount of exports. This outcome is consistent with the hypothesis that young firms are likely to be more credit constrained and, as a result, more dependent on internal resources that are more closely correlated with the evolution in market demand. Finally, inexperienced YICs rely more on their skill endowments.

These results may have important implications. Indeed, based on our findings, policy makers should design their interventions on the understanding that different drivers may play distinct roles in boosting the innovation activity of firms of different age.

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Table 2.1. Composition of the panel

Time obs.	Nº of firms	%	Cum. %	Nº of obs.
1	505	14.47	14.47	505
2	540	15.48	29.95	1,080
3	625	17.91	47.86	1,875
4	192	5.50	53.37	768
5	192	5.50	58.87	960
6	238	6.82	65.69	1,428
7	135	3.87	69.56	945
8	60	1.72	71.28	480
9	133	3.81	75.09	1,197
10	50	1.43	76.53	500
11	130	3.73	80.25	1,430
12	70	2.01	82.26	840
13	69	1.98	84.24	897
14	95	2.72	86.96	1,330
15	110	3.15	90.11	1,650
16	44	1.26	91.37	704
17	301	8.63	100.00	5,117
Total	3,489	100.00		21,706

Note: the final sample only comprises firms for which a lag of the dependent variable is available. This implies that t=1 refers to firms that are observed for at least two periods, t=2 corresponds to firms that are observed for three periods and so on.

Table 2.2. Sample size according to age threshold and innovative status

	ALL FIRMS		MATURE		YOUNG	
	Nº of firms	*Nº of obs.*	*Nº of firms*	*Nº of obs.*	*Nº of firms*	*Nº of obs.*
No R&D	2,333 (66.87)	14,535 (66.96)	1,414 (60.92)	11,384 (64.28)	919 (78.68)	3,151 (78.87)
R&D	1,156 (33.13)	7,171 (33.04)	907 (39.08)	6,327 (35.72)	249 (21.32)	844 (21.13)
Total	3,489 (100)	21,706 (100)	2,321 (66.52)	17,711 (81.59)	1,168 (33.48)	3,995 (18.41)

Note: percentages in brackets.

Table 2.3. Transition probabilities of innovator status

		Performer in t	
Performer in t-1		*No R&D*	*R&D*
ALL FIRMS	*No R&D*	94.23	5.77
	R&D	12.17	87.83
MATURE	*No R&D*	93.98	6.02
	R&D	11.24	88.76
YOUNG	*No R&D*	94.81	5.19
	R&D	19.36	80.64

Table 2.4. Descriptive statistics: mean and standard deviation (overall, between and within) of the variables; all firms - mature firms - young firms

	ALL FIRMS				*MATURE*				*YOUNG*			
	Mean	*Std. Dev.*			*Mean*	*Std. Dev.*			*Mean*	*Std. Dev.*		
		Overall	*Between*	*Within*		*Overall*	*Between*	*Within*		*Overall*	*Between*	*Within*
RD_d	0.330	0.470	0.426	0.234	0.357	0.479	0.435	0.234	0.211	0.408	0.372	0.191
LRD	1.677	2.666	2.545	1.080	1.855	2.766	2.618	1.113	0.889	1.979	1.968	0.703
CONC	0.557	0.497	0.418	0.314	0.573	0.495	0.422	0.304	0.484	0.500	0.435	0.283
DIVER	0.142	0.349	0.306	0.208	0.141	0.348	0.310	0.200	0.143	0.351	0.313	0.181
DYNAM	0.251	0.433	0.301	0.350	0.244	0.430	0.303	0.344	0.280	0.449	0.341	0.316
LEXP_1	4.190	4.076	3.935	1.293	4.567	4.101	3.967	1.265	2.519	3.505	3.399	1.059
LSUB_1	0.506	1.726	1.372	1.095	0.558	1.807	1.446	1.136	0.274	1.280	1.023	0.739
SKILL	4.169	6.810	6.905	2.991	4.396	6.852	7.125	2.921	3.163	6.530	6.433	2.475
LEMP	4.112	1.435	1.432	0.235	4.248	1.447	1.430	0.221	3.510	1.210	1.233	0.199
Obs	21,706				17,771				3,995			

Table 2.5. Sectoral composition (2-digit manufacturing sector) and average employment for mature and young firms

INDUSTRY	*YOUNG*			*MATURE*		
	N. of Obs.	*%*	*Av. Emp.*	*N. of Obs.*	*%*	*Av. Emp.*
Meat products	112	2.8	86	559	3.2	223
Food and tobacco	340	8.5	85	1,833	10.4	211
Beverage	34	0.9	56	367	2.1	255
Textiles and clothing	470	11.8	54	1,763	10.0	141
Leather, fur and footwear	172	4.3	21	480	2.7	47
Timber	203	5.1	48	467	2.6	101
Paper	100	2.5	129	508	2.9	169
Printing	268	6.7	27	910	5.1	142
Chemicals and pharmaceuticals	152	3.8	279	1,252	7.1	263
Plastic and rubber products	270	6.8	102	930	5.3	176
Non-metal mineral products	251	6.3	80	1,260	7.1	151
Basic metal products	97	2.4	277	634	3.6	462
Fabricated metal products	456	11.4	36	1,771	10.0	118
Machinery and equipment	233	5.8	72	1,275	7.2	190
Computer products, electronics and optical	46	1.2	230	261	1.5	242
Electric materials and accessories	214	5.4	181	930	5.3	238
Vehicles and accessories	139	3.5	566	858	4.8	920
Other transport equipment	44	1.1	453	370	2.1	763
Furniture	306	7.7	37	882	5.0	94
Other manufacturing	88	2.2	28	401	2.3	88
SAMPLE	3,995	100.0	103	17,711	100.0	228

Table 2.6. Results from the dynamic type 2 tobit estimates

SELECTION EQUATION								
	TOTAL		*MATURE*		*YOUNG*		*Diff. Mature vs Young*	
RD_d_1	1.911***	(48.83)	1.998***	(46.65)	1.635***	(13.61)	0.363***	(2.84)
CONC	0.091***	(2.71)	0.090**	(2.42)	0.109	(1.44)	-0.019	(-0.22)
DIVER	0.106**	(2.38)	0.095*	(1.92)	0.121	(1.20)	-0.026	(-0.23)
DYNAM	0.158***	(4.54)	0.151***	(3.89)	0.201***	(2.59)	-0.050	(-0.58)
LEXP_1	0.047***	(7.89)	0.048***	(7.32)	0.039***	(2.86)	0.009	(0.57)
LSUB_1	0.055***	(4.86)	0.050***	(4.13)	0.097***	(2.90)	-0.047	(-1.33)
SKILL	0.014***	(4.98)	0.014***	(4.69)	0.011*	(1.84)	0.004	(0.55)
LEMP	0.204***	(11.05)	0.201***	(9.82)	0.181***	(4.13)	0.019	(0.39)
INTERCEPT	-3.074***	(-20.90)	-3.004***	(-18.39)	-3.314***	(-8.58)	0.310	(0.74)
Nº of firms	21,706		17,711		3,995		-	
MAIN EQUATION								
LRD_1	0.297***	(33.96)	0.302***	(32.64)	0.242***	(8.35)	0.060**	(1.99)
DYNAM	0.078***	(2.89)	0.077***	(2.71)	0.178**	(2.22)	-0.100	(-1.18)
LEXP_1	0.017***	(3.02)	0.011*	(1.84)	0.062***	(3.48)	-0.051***	(-2.73)
LSUB_1	0.035***	(6.26)	0.037***	(6.45)	0.028	(1.56)	0.009	(0.47)
SKILL	0.025***	(10.00)	0.023***	(8.87)	0.038***	(5.31)	-0.015**	(-1.97)
LEMP	0.602***	(32.71)	0.615***	(30.61)	0.545***	(11.71)	0.070	(1.39)
INTERCEPT	-0.722***	(-5.39)	-0.825***	(-5.85)	-0.581	(-0.91)	-0.245	(-0.37)
Nº of Obs.	7,171		6,327		844		-	
EXTRA PARAMETERS								
Init.cond. (RD_d)	0.662***	(12.27)	0.623***	(10.83)	0.747***	(4.61)	-	-
Init.cond. (LRD)	0.062***	(8.51)	0.058***	(7.44)	0.062***	(2.66)	-	-
ρ_{u1u2}	0.414***	(14.25)	0.432***	(14.12)	0.404***	(4.01)	-	-
$\rho_{\varepsilon1\varepsilon2}$	0.161***	(3.82)	0.180***	(4.15)	0.102	(0.82)	-	-
σ_{u1}	-0.755***	(-12.28)	-0.795***	(-10.89)	-0.935***	(-2.84)	-	-
σ_{u2}	-0.664***	(-21.07)	-0.685***	(-19.94)	-0.430***	(-5.48)	-	-
$\sigma_{\varepsilon2}$	-0.072***	(-7.51)	-0.079***	(-7.74)	-0.102***	(-3.14)	-	-

t- statistics in brackets: * Significant at 10%; **5%;***1%
All regressions include time and industries dummies (results available upon request).

Appendix 2

Table A2.1. The variables: acronyms and definitions.

Dependent Variables	
RD_d	Dummy =1 if firm's R&D expenditures are positive
LRD	Log of firm's total R&D expenditures (the cost of intramural R&D activities and payments for outside R&D contracts)
Explanatory variables	
CONC	Dummy =1 if the firm reports that its main market consists of 10 dominant firms or less; 0 otherwise
DIVER	Dummy=1 if the firm is characterised by product diversification; 0 otherwise
DYNAM	Dummy =1 if the firm reports that its main market is expansive; 0 if it is stable or recessionary
LEXP	Log of the total amount of exports
LSUB	Log of the total amount of public funding received by the firm
SKILL	Ratio of engineers and graduates over total employment
LEMP	Log of the total number of firm's employees

Table A2.2. Correlation between the explanatory variables and their corresponding Mundlak means

CONC	0.76
DIVER	0.79
DYNAM	0.57
LEXP_1	0.95
LSUB_1	0.77
SKILL	0.90
LEMP	0.99

Chapter III
Young firms and innovation: a microeconometric analysis

3.1 Introduction

Increasing interest is being shown by both the scientific community and policy makers in the role of young innovative companies (YICs), defined as innovative firms younger than a given age threshold and operating in all the sectors of the economy. This definition differs from that of the so-called "New Technology Based Firms" (NTBFs, see Storey and Tether, 1998; Colombo and Grilli, 2005) which are newborn YICs operating in the high-tech sectors[19].

Indeed, YICs are seen as key actors in the process of implementation of the new technologies, in contributing to the renewal of the industrial structure and ultimately in fostering aggregate economic growth. For instance, several EU Member states have introduced new measures to support the creation and growth of YICs, especially by improving their access to funding (see BEPA, 2008; Schneider and Veugelers, 2010). In fact, one of the possible explanations of the transatlantic productivity gap could be

[19] While in this study we compare YICs with mature innovative incumbents, a related stream of literature investigates the role of innovation in facilitating the entry and post-entry performance of newborn firms (see Audretsch and Vivarelli, 1996; Arrighetti and Vivarelli, 1999; Cefis and Marsili, 2006). Finally, in this paper only innovative firms are studied, while another related field of studies investigates the different propensity to innovate according to a firm's age (see Hansen, 1992; Huergo and Jaumandreu, 2004).

found in the revealed capacity of the US economy to generate an increasing flow of young innovative firms which manage to survive and introduce new products, taking their place at the core of emerging sectors. In contrast, young European firms reveal lower innovative capacity and most of them are doomed to early failure, the process resulting in churning rather than innovative industrial dynamics (see Bartelsman *et al*., 2004; Santarelli and Vivarelli, 2007; Moncada-Paternò-Castello, *et al*., 2010).

There are several different sources of innovation at the firm level; together with in-house and external R&D activities, technological acquisition (TA) in its embodied (machinery and equipment) and disembodied components also has to be taken into account. This input-output framework can be seen as an extension of the "Knowledge Production Function" (KPF, initially put forward by Griliches, 1979), a feasible tool for describing the transformation process running from innovative inputs to innovative outputs.

While most previous microeconometric research has focused on the R&D-Innovation-Productivity chain (see next section), few studies have explicitly discussed the role of TA and the possible differences in the KPF across firms of different ages. By using microdata from the European Community Innovation Survey 3 (CIS 3) for the Italian manufacturing sector, one of the novelties of this paper lies in the authors' investigation of whether R&D and TA lead to significant differences in determining innovative output in firms of different ages. In particular, it will be tested whether the KPF of YICs exhibits some peculiarities in comparison with what emerges in the case of mature incumbent firms.

The remainder of the paper is organised as follows: a discussion of the theoretical framework on which this work is based (Section 2) is followed by a description of the data and indicators used in the empirical analysis and by a discussion of the adopted econometric methodology (Section 3). Subsequently, the empirical outcomes derived from the descriptive analysis and the econometric estimates are discussed in Section 4. Section 5 concludes the paper by briefly summarising the main findings obtained.

3.2 The literature

Previous economic literature has taken R&D and patents as a starting point for the analysis of innovative activities across economies, industries and firms. In particular, the relationship between innovative inputs and outputs explicitly appears as one of the components of those analyses whose main target is to measure the returns on innovation. In this stream of literature, the first contribution to discuss the innovative input-output relationship was by Griliches (1979 and 1990), through a three-equation model in which one of the equations is what he called the Knowledge Production Function (KPF), a function intended to represent the transformation process leading from innovative inputs (R&D) to innovative outputs (patents)[20]. Similarly, the KFP is also included in the models provided by Crèpon *et al*. (1998) and Lööf and Heshmati (2001).

However, for the particular purpose of this paper, most of the previous empirical tests of the KPF suffer from two main limitations. Firstly, the relationship between innovation inputs and innovation outputs is not their main focus but rather a secondary equation, ancillary to the authors' main purpose of investigating firms' performance in terms of productivity and/or profitability. Secondly, and more important, the original KPF was put forward as a simplistic link between R&D and patents. Historically

[20] The other two equations in Griliches' simultaneous model represent the production function (augmented by the innovation term) and the determinants of R&D investment. See also Hall (1996), Hall (2000), Mairesse and Mohnen (2002), Harhoff *et al*. (2003) and Hall *et al.* (2005).

driven by relative availability with respect to other measures of innovation, the relationship between a firm's R&D investment and patenting activity leaves room today for a more comprehensive approach to the determinants of its innovativeness. In particular, nowadays innovation surveys provide more precise and comprehensive measures of both innovative inputs and outputs.

As far as innovative outputs are concerned, a recent literature has recognized that patents may not be the sole measurable outcome of the KPF, opening the way to the direct investigation of the product and process innovative outcomes as they are perceived by the supplier firm and/or by the market (see Griffith *et al.*, 2006; Parisi *et al.*, 2006; Hall *et al.*, 2008 and 2009).

By the same token, different innovation outputs can be seen as the outcomes of several innovation inputs and not only as the consequence of formal R&D investments[21]. More specifically, it is important to consider the role of technological acquisition (TA), both through 'embodied technical change' acquired by means of investment in new machinery and equipment, and through the purchasing of external technology incorporated in licences, consultancies, and know-how.

The embodied nature of technological progress and the effects related to its spread in the economy were originally discussed by Salter (1960), Solow (1960) and Jorgenson (1966) and are currently considered in the macroeconomic models of (endogenous) economic growth (see Hulten, 1992; Greenwood *et al.*, 1997; Hercowitz, 1998).

However, at the microeconomic level, only an extended and more articulated view of the innovative process within and across firms (see Nelson and Winter, 1982 and Dosi, 1988) has allowed to move from R&D as considered the only innovative input to a vision where technological change is

[21] This broader perspective is also endorsed in methodological advice as to the collection of data regarding innovation; in particular, this is well represented by the shift from the R&D-focused Frascati Manual ('Guidelines for the collection of R&D data', first published in 1963) to the Oslo Manual in the 1990s (OECD, 1997).

implemented both through R&D expenditures and through investment and scrapping. In this context, vintage capital models have described an endogenous process of innovation in which the replacement of old equipment is the main way through which firms update their own technologies (see Freeman *et al.*, 1982; Freeman and Soete, 1987). By the same token, input-output models have made clear that the innovative pace in a given sector and/or firm is strictly linked to that of its supplying sectors/firms *via* embodied technological change (see Leontief and Duchin, 1986; Kalmbach and Kurz, 1990; Meyer-Krahmer, 1992; Wolff and Nadiri, 1993[22]).

In this context, we wonder whether YICs differ from mature incumbents in their input-output innovative relationships. Are YICs more R&D-based and conducive to a science-based reorientation of the current industrial structure? Or – in contrast - are YICs weaker than innovative incumbents and so less R&D-based and basically dependent on embodied technological change and external knowledge provided by suppliers, larger mature firms and research institutions?

The hypothesis of small and newly established firms being more science-based and technologically advanced is consistent with the entrepreneurial process of 'creative destruction' (Schumpeter, 1934; the so-called Schumpeter Mark I), while the process of 'creative accumulation' calls for large and established firms to take a leading role in the innovative process (Schumpeter, 1942; Schumpeter Mark II). Adopting an evolutionary terminology, the former context can be seen as an 'entrepreneurial regime', where new firms and the industrial dynamics are the basic factors of change,

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[22] More recently, the role of embodied technological change and of intersectoral linkages as vehicle of innovation in the receiving sectors/firms is under the lens of the scholars of international technological diffusion (see Robbins, 2003 for the definition of the so-called 'skill-enhancing trade' due to import of capital goods incorporating skill biased technological change; Keller, 2004 for a general survey; Meschi and Vivarelli, 2009 for the consequences of the skill-enhancing trade on inequality in the developing countries; Lööf and Andersson, 2010 for the impact of import from advanced countries – the G7 - on the productivity of the receiving one).

while the latter can be considered a ‘routinized regime’, where larger and older incumbents are the engines of change and lead the innovative process (see Winter, 1984; Malerba and Orsenigo, 1996; Breschi *et al.*, 2000).

Indeed, when focusing on all the industrial sectors and not only the emerging or the high-tech ones, several arguments sustain the view that larger mature firms might turn out to be more R&D based than their younger counterparts. Firstly, mature larger incumbents are not affected by liquidity constraints since they have both easier access to external finance and more internal funds to support R&D activities which are both costly and uncertain. Secondly, larger incumbent firms possess a higher degree of market power and so enjoy a higher degree of ‘appropriability’ (Gilbert and Newbery, 1982). Empirically, Cohen and Klepper (1996) provide stylised facts supporting the view that the likelihood of a firm carrying out R&D increases with size, while Mairesse and Mohnen (2002) highlight the scale economies and the differences in the organisation of work that make larger established incumbents more inclined to carry out R&D activities. Thirdly, learning economies (see Arrow, 1962; Malerba, 1992) are often crucial in innovative dynamics and older (experienced) firms are obviously at an advantage from this perspective.

However, not all innovative firms are large established corporations. Indeed, economic literature supports the hypothesis that small and young firms face a different technological and economic environment from large mature firms with respect to their innovative activities (see Acs and Audretsch, 1988 and 1990; Acs *et al.*, 1994; Ortega-Argilés *et al.*, 2009). In particular, as discussed above, R&D does not represent the sole input through which firms can produce some innovative outcomes. While the financial and competitive reasons discussed above can hamper an R&D-based innovative strategy for YICs, it seems much easier for them to rely on the market and choose ‘to buy’ instead of ‘to make’ technology (Acs and Audretsch, 1990). One of the hypotheses to be tested in this paper is therefore whether innovation in YICs relies more on external sources of knowledge than on formal in-house R&D.

This hypothesis appears even more plausible in a middle-technology economy, such as that of Italy, where middle-tech and traditional sectors represent the core of the industrial structure (for evidence on the crucial role of embodied technical change and other external sources of knowledge in spurring innovation in the medium and low-tech sectors, see Santarelli and Sterlacchini, 1994 and Santamaría *et al.*, 2009).

In other words – in the specific Italian 'national innovation system' (see Freeman, 1987, Lundvall, 1992 and Nelson, 1993, for an introduction to the concept; Malerba, 1993, for an application to the Italian case) - NTBFs may be an exception, while for YICs the main way to acquire knowledge might be through embodied technical change and technological acquisition (for previous evidence on the role of embodied technological change in fostering innovation in Italian manufacturing firms, see Santarelli and Sterlacchini, 1990; Conte and Vivarelli, 2005).

3.3 Dataset, indicators and methodology

The empirical analysis was carried out using microdata drawn from the third Italian CIS, conducted over a three-year period (1998-2000) by the Italian National Institute of Statistics (ISTAT). This survey is representative at both the sector and the firm size level of the entire population of Italian firms with more than 10 employees.

In collecting the CIS3 questionnaires, ISTAT adopted a weighting procedure that relates the sample of firms interviewed to the entire population[23] (ISTAT, 2004).

The dataset comprises a set of general information (main industry of affiliation, group belonging, turnover, employment, exports) and a (much larger) set of innovation variables measuring the firms' innovativeness, economic and non-economic measures of the effects of innovation, subjective evaluations of factors hampering or fostering innovation, participation in cooperative innovation activities and access to public funding. The response rate was 53%, determining a full sample size of 15,512 firms.

Given the original CIS3 database, we proceeded to further select the investigated firms in accordance with the following steps.

1. Firstly we wiped out firms operating in the primary, service and construction sectors, remaining with 9,034 manufacturing firms (Table 3.3 provides the distribution of firms across the 3-digit manufacturing sectors). Indeed, the innovative indicators adopted in this study (see the next Sections 3.1 and 3.2) are unambiguous only referring to the manufacturing firms.

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[23] Firm selection was carried out through a 'one step stratified sample design'. The sample in each stratum was selected with equal probability and without reimmission. The stratification of the sample was based on the following three variables: firm size, sector, regional location. Technically, in the generic stratum h, the random selection of n_{h} sample observations among the N_{h} belonging to the entire population was realized through the following procedure:
- a random number in the 0-1 interval was attributed to each Nh population unit;
- Nh population units were sorted by increasing values of the random number;
- units in the first nh positions in the order previously mentioned were selected.
Estimates obtained from the selected sample are very close to the actual values in the national population. The weighting procedure follows Eurostat and Oslo Manual (OECD, 1997) recommendations: weights indicate the inverse of the probability that the observation is sampled. Therefore, sampling weights ensure that each group of firms is properly represented and correct for sample selection. Moreover, sampling weights help in reducing heteroskedasticity commonly arising when the analysis focuses on survey data. It is important to note that this sample weighting was carried out ex-ante by ISTAT in the process of providing the original data, therefore it is not implying any cleaning procedure by the authors.

2. Secondly, the sample was cleaned of outliers and firms involved in mergers or acquisitions (M&A) during the previous three years; in fact, M&A may break the link between innovative inputs and outputs, a link that must be studied within the context of a single firm. Think, for instance, to a given firm making 'shopping' of a very innovative firm: this firm would be erroneously assigned an innovative attribute actually entirely due to another (no longer existing) economic agent. We thus ended up with 7,965 innovating and not-innovating firms.
3. Thirdly, the sub-sample of innovators we were interested in was singled out following the standard practice of identifying innovators as those firms declaring that in the previous three years they had introduced product or process innovations, or had started innovative projects (then dropped or still-to-complete at December 31st, 2000). Indeed, this is the definition adopted by the European CIS collectors – including ISTAT – as a filter to save non-innovators having to plough through all the questions not relevant to them (with the risk of non-innovating firms not responding to the rest of the questionnaire). Therefore, firms identified as non-innovators are allowed to skip a large number of 'innovation questions', leaving researchers with very little information about their propensity to innovate or to invest in innovative inputs. This means that the CIS database provides information relevant to this study only for innovative firms. However, given that our aim is that of analyzing the nature of the relationships within the innovative process and not - for example - the effect of different inputs in determining the probability of innovating, this data limitation does not raise a problem of selection bias. Since we are interested in the internal mechanisms of the innovative process, we have to focus on a randomly selected sample of innovative firms; in other words, randomness must hold within the

innovative sub-sample, not in comparison with the non-innovative one where such mechanisms are obviously absent (for a study based on a comparison between innovative and non-innovative Italian firms, see Parisi *et al.*, 2006). At the end of this step, we ended up with 3,045 innovative firms.

4. Fourthly, this sample was further reduced to 2,713 firms by keeping only firms the age of which was available and investing in at least one of the four innovative inputs we focus on. In fact, the information about age is not included in the CIS questionnaire and was kindly provided by ISTAT when available. Finally, firms declaring an innovation output but not declaring any innovative input were dropped out since inadequate for our adopted specification (see eq.1 in Section 3.4).
5. Fifthly, YICs were identified as young firms with less than 8 years of activity (293 out of 2,713). The 8 years age was chosen in order to reach a satisfactory degree of representativeness of the sub-sample of YICs - here more than 10% of the entire sample - without increasing the age threshold too much. However, the estimates discussed in Section 3.4 were replicated using a larger sample of young firms no more than 10 years old; the results, available from the authors upon request, do not change substantially.

3.3.1 Innovative outputs

Innovative outputs can be distinguished with respect to their position in the innovation process. For instance, while patents are better defined as the outcome of the inventive process, product innovation properly represents the result of the market-oriented innovative process.

One of the advantages of the CIS dataset is the availability of a dummy variable (PROD) based on a survey question asking the firm whether it has introduced a new (or substantially improved from a technological point of view) product. However, even though product innovation is driven by demand considerations, it represents a pre-market result and could be simply related to the subjective perception of the supplier firm (possibly affected by overconfidence in the actual market chances).

In contrast, the share of sales deriving from innovative products – also collected by the CIS survey - represents an *ex-post* result in which the market has positively welcomed the new products introduced by the firm (see Barlet *et al.,* 2000; Mairesse and Mohnen, 2002). The main equation of the model proposed in this paper (see the following eq.1) assumes the indicator of commercial success (TURNIN) as the most comprehensive and satisfactory indicator of firm's innovativeness.

Taking these considerations and the interpretative background discussed in Section 2 into account, this paper uses two available output indicators for the empirical analysis: namely, the introduction of product innovation (PROD), and the share of turnover (sales) derived from innovative products (TURNIN). This sales-weighted measure of innovation is the only continuous output indicator provided by CIS and it indicates the intensity of innovation (Lööf and Heshmati, 2002; Mairesse and Mohnen, 2002).

It is worth emphasizing the link adopted in the questionnaire design; this link goes from product innovation (PROD) to the sales ratio indicator (TURNIN), since only firms that declare to have introduced product innovation can record a positive percentage of their sales as being derived from product innovation[24]. Therefore, it is the very nature of the questionnaire design which raises the issue of sample selection that will be discussed in the next methodological Section 3.4.

[24] While CIS innovative firms comprise companies active in process and/or product innovation, PROD makes a selection excluding those firms solely active in process innovation and keeping those firms generating either product innovation solely or both product and process innovation.

3.3.2. Innovative inputs

Bearing in mind the theoretical discussion presented in Section 2, four innovative inputs are used in this paper: in-house expenditures in formal Research and Development (intra muros R&D = IR); Research and Development outsourced to other firms or research institutes (extra muros R&D = ER); expenditures in embodied technological change (innovative investment in equipment and machinery = MAC); and expenditures in technology acquisition (disembodied technology such as know-how, projects and consultancies, licenses and software = TA).

3.3.3. Control variables

CIS3 provides further information on firms beyond their innovative activity. Econometric estimates in this paper adopt some of these indicators as further controls and explanatory variables. Attention is paid to the following control variables:

1. Firm's export propensity (EXPint): global competition can spur innovation and capabilities, while technologically inactive firms are doomed to exclusion from the international arena (e.g. Archibugi and Iammarino, 1999; Narula and Zanfei, 2003[25]).

2. Firm's belonging to an industrial group (IG): Mairesse and Mohnen (2002) underline the expected innovative benefits due to easier access to (internal) finance and to the effect of intra-group knowledge spillovers for firms that are members of industrial groups.

[25] While 'learning by export' may be an important stimulus to innovation and technological upgrading (see Melitz, 2003; Yeaple, 2005), a reverse causation can also be put forward since most innovative firms are either more likely to penetrate foreign markets or to self-select themselves as more suitable to engage in foreign competition (see Clerides*, et al.,* 1998). The cross-sectional nature of our dataset does not permit to properly disentangle this endogeneity issue; however, this caveat has to be taken into account in the interpretation of the results.

3. Firm's access to policy support (SUPPORT): a government subsidy or a fiscal incentive should increase a firm's innovative performance, although the empirical evidence on this is quite controversial[26].

4. Firms participating in a cooperation agreement (COOP): as regards the important role of cooperation agreements in affecting the innovative output of firms, see Cassiman and Veugelers (2002), Piga and Vivarelli (2003 and 2004), Fritsch and Franke (2004), Parker (2008).

5. Appropriability: the availability and use of different instruments for achieving a larger degree of appropriability of the innovation rent, such as patents (PATENT), trademarks, secrecy, etc. (PROT) (see Levin *et al.*, 1987) should positively affect the innovative performance.

6. While the recognized obstacles to innovation (such as financial constraints or organizational hindrances) (HURDLE) should obviously damage innovative performance, the occurrence of other forms of innovation (such as organizational change, see Bresnahan *et al.*, 2002; Hitt and Brynjolfsson, 2002; Piva *et al.*, 2005) (OTHERIN) should be complementary to the four innovative inputs described in the previous section.

[26] In fact, while public funding should stimulate (in absolute terms) both the input and the output side of innovation, a crowding out effect seems to operate, displacing (totally or partly) privately funded innovation activities. Using a dataset of firms which benefited from the Small Business Innovation Research Program, Wallsten (2000) even comes to the conclusion that R&D grants completely crowd out firm-financed R&D spending, dollar for dollar. The view of Gonzáles *et al.* (2005) is much more optimistic: they found no evidence of crowding out. Using an unbalanced panel of more than 2000 Spanish manufacturing firms, the authors show that government intervention stimulates R&D activities. Midway between such extreme results, the majority of existing empirical literature on the subject shows that public support fosters innovation, crowding out effects operating only partially (see Busom, 2000).

Finally, Pavitt's sectoral dummies (Pavitt, 1984) were added to the econometric specification in order to control for the different sectoral technological opportunity and appropriability conditions.

Table 3.1 describes the variables used in the empirical analysis, while Table A3.1 in the Appendix reports the CIS questions on the basis of which the different variables were constructed.

Table 3.2 reports the corresponding descriptive statistics, distinguishing all firms, mature firms and YICs and – within each of these three categories – innovative firms from the subsets characterised by having introduced a product innovation.

< INSERT TABLES 3.1 AND 3.2 >

Table 3.3 reports the sectoral compositions of the two subsamples of mature firms and YICs: as can be seen, with regard to most sectors and the four Pavitt (1984) categories, no significant differences emerge; however - to be on the safe side - all the regressions were controlled for Pavitt's sectoral dummies. In contrast, as far as the size of the firms is concerned, YICs turn out to be relatively smaller (112 employees on average) than their older counterparts (183 employees). This means that the subsample of YICs - in contrast with the mature firms - may be affected by those advantages and disadvantages discussed at the end of Section 2 with reference to smaller young innovative firms.

< INSERT TABLE 3.3 >

3.3.4. Econometric issues

Equation (1) describes the general specification adopted for the aggregate empirical test of the innovative input-output relationship:

$$TURNIN_i = C + \beta_1 IRint_i + \beta_2 ERint_i + \beta_3 MACint_i + \beta_4 TAint_i + \sum \beta_J X_{ji} + \sum \gamma_k PAVITT_{ki} + \varepsilon \quad \textbf{(1)}$$

where C is the constant, i is the firm-index, TURNIN represents the innovative output in terms of the percentage of sales due to innovative products, IR, ER, MAC and TA indicate the innovative inputs we are interested in, X is the vector of the (max j=8) control variables and PAVITT are the sectoral dummies (Science-based, Scale intensive, Specialised suppliers, with the Suppliers-dominated as the default category; k=3).

Consistently with the dependent variable, the four innovative inputs were normalized by sales; this makes the inputs homogeneous to the output and also controls for the scale effect due to the different sizes of the investigated firms. In the Appendix, Table A3.2 reports the correlation matrix for the entire sample; as can be seen, all the correlation coefficients are less than 0.370, showing that data are not affected by serious collinearity problems.

As a consequence of the questionnaire's design, the adopted sales-weighted measure of a firm's innovativeness (TURNIN) assumes a positive value only for firms that have introduced product innovation (PROD). This raises an obvious problem of sample selection that has to be dealt with. In particular equation (1) was tested jointly with a selection probit equation (2) of the type:

$$P(PROD_i{=}1) = C + \beta_1 IRint_i + \beta_2 ERint_i + \beta_3 MACint_i + \beta_4 TAint_i + \sum \beta_J Z_{ji} + \sum \gamma_k PAVITT_{ki} + \varepsilon_i \quad \textbf{(2)}$$

Where Z is an extended vector of controls in equation (1), with $X \in Z$. More specifically, X and Z were differentiated taking into account the statistical significance of the different controls in the two equations, the occurrence of convergence in all the three models and the need for a homogeneous comparison between them. However, results are robust to different specifications of the sample selection model (available upon request).

Both the high values of the correlation coefficients (ρ) between the selection and the main equation and the statistical significances of the Mills ratios in the three models (all firms, mature firms, YICs) (see Table 3.4) confirm the validity of the choice of this Heckman-Type (see Heckman, 1979) specification.

Besides these statistical reasons, the advantage of running a Heckman-Type model is the possibility to separately assess the impact of the different regressors on: (1) the probability to engage in product innovation (PROD); (2) the intensity of innovation (TURNIN). As we will discuss in the next Section, this is important from an interpretative point of view.

< INSERT TABLE 3.4 >

3.4 Empirical results

Table 3.4 reports the econometric results of the sample selection model applied to the entire sample and separately to the two sub-samples of the mature incumbents and the YICs. As can be seen, in-house R&D is important in increasing the likelihood of product innovation for the entire sample, although this link is less significant for the YICs. More importantly and in contrast with the mature firms, innovation intensity (TURNIN) is not related to internal R&D (IR) as far as the YICs are concerned. Far from being NTBFs, Italian YICs do not turn out to be R&D based, but rather dependent on external sources of knowledge.

The above result becomes obvious if we turn our attention to the other three innovative inputs. Neither external research (ER) nor technological acquisitions (TA) seem to play a significant role in spurring product innovation in Italian manufacturing firms. However, in contrast with what happens for well-established incumbents, their impact is positive, although not significant, with regard to the YICs. Although statistically very weak, this outcome may suggest a possible role of ER and TA in facilitating innovation in the young firms.

Much more statistically robust is the outcome concerning the 'embodied technical change' variable MAC. While rendering product innovation less likely[27], MAC is positively and significantly linked to the innovation intensity in all the three models.

However, the coefficient is more than double the size in the case of the YICs. This means that Italian YICs are particularly dependent on the embodied technical change incorporated in machinery and equipment purchased from external sources. Together with what was found in relation to the non-significant impact of IR, this means that the investigated YICs lack internal technological capabilities, while they are massively dependent on technologies coming from other firms through input-output relationships. On the whole, these results highlight a potential weakness of Italian YICs, which seem to lack an endogenous capacity to sustain their own innovative activities.

Briefly looking at the control variables (see Section 3.3), not surprisingly we notice that exporting and science-based YICs are more likely to perform better in terms of innovative intensity. Instead, and in contrast with the mature firms, YICs do not seem to be established enough to be responsive to variables

[27] This result is consistent with previous studies (see Conte and Vivarelli, 2005) and is not surprising; indeed, it can be seen as a direct consequence of the sample selection procedure. In fact, MAC is strictly related to process innovation, which is the innovative category excluded in the selected sample. The 615 excluded firms are those only engaged in process innovation, while the 2,098 firms included are those exhibiting either product innovation only or product and process innovation jointly.

such as HURDLE, OTHERIN and PROT. This can be seen as a sign that these firms are still too young and inexperienced to set up a proper appropriability regime and to develop complementary innovative strategies.

The results from a possible alternative TOBIT methodology – pooling together those firms not engaged in product innovation with those involved into it – are reported in Table 3.5. As mentioned at the end of the previous section, this approach does not allow disentangling the impact on the probability to introduce a product innovation from the impact on the intensity of innovation[28]. However, the main outcome showing that Italian YICs are mainly dependent on embodied technical change, with in-house R&D not playing a significant role, is fully confirmed by the TOBIT estimates.

< INSERT TABLE 3.5 >

3.5 Concluding remarks

This paper has discussed the determinants of innovative output in YICs and mature firms, by looking both at firms' internal and external R&D activities and at the acquisition of external technology in its embodied and disembodied components. These input-output relationships have been tested through a

[28] For instance, we miss the possibility to single out the peculiar role of MAC within the mature firms, rendering product innovation less likely but increasing innovation intensity: not surprisingly, the two significant and opposite effects singled out in the first two models of Table 4 average down into a not significant impact in the first two columns of Table 5.

sample selection procedure which takes into account the fact that our measure of innovative performance only refers to product innovation.

Looking at the aggregate results, it turns out that in-house R&D is closely linked to innovative performance, while external R&D does not seem to play a relevant role in Italian manufacturing. However, once the YICs are distinguished from the established firms, in the former internal R&D expenditures no longer play a role in increasing innovation intensity, although they do increase the probability of engaging in product innovation. The crucial innovative input for YICs turns out to be the external acquisition of technology in its embodied component (MAC). The correspondent coefficient is also positive and significant with regard to the mature firms, but it more than doubles in the case of the YICs.

These results suggest that in a intermediate-technology context such as Italian manufacturing where middle-tech and traditional sectors represent the core of the industrial structure, on average YICs cannot be considered as NTBFs. Rather, they appear to be economic entities which need to acquire external knowledge in order to foster their own innovation activity and are therefore crucially dependent on the external environment.

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Table 3.1. The variables: acronyms and definitions

Innovative input variables	
IRint	Internal R&D expenditure in 2000, normalized by total turnover
ERint	External R&D expenditure in 2000, normalized by total turnover
MACint	Investments in innovative machinery and equipment in 2000, normalized by total turnover
Taint	Technological acquisitions in 2000, normalized by total turnover
Innovative output variables	
TURNIN	Share of firm's total sales due to sale of new products
PROD	Product innovation: dummy = 1 if TURNIN > 0
Firm's general characteristics	
EXPint	Export intensity ((turnover from export) / turnover)
IG	Dummy = 1 if the firm belongs to an industrial group
Innovative-relevant information	
SUPPORT	Dummy = 1 if the firm has received public support for innovation
COOP	Dummy = 1 if the firm takes part into cooperative innovative activities
PATENT	Dummy = 1 if the firm uses patents
PROT	Dummy = 1 if the firm adopts other instruments of protection than patents
HURDLE	Dummy = 1 if the firm has faced some kind of obstacle to innovation
OTHERIN	Dummy = 1 if the firm has realized managerial, strategic or organizational innovation
Pavitt sectoral dummies	
SB	Dummy = 1 if science-based firm
SI	Dummy = 1 if scale intensive firm
SS	Dummy = 1 if specialized supplier firm
SD	Dummy = 1 if supplier-dominated firm

Table 3.2. Descriptive statistics: mean values and standard deviations of the variables; entire sample and two separate subsamples

	ALL FIRMS				MATURE FIRMS				YOUNG FIRMS (YICs)			
	2,713 OBS		**2,098 OBS**		**2,420 OBS**		**1,870 OBS**		**293 OBS**		**228 OBS**	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Innovative input variables												
IRint	0.013	0.026	0.015	0.028	0.013	0.025	0.015	0.027	0.014	0.032	0.017	0.036
ERint	0.002	0.009	0.002	0.010	0.002	0.008	0.002	0.009	0.002	0.011	0.003	0.013
MACint	0.035	0.078	0.028	0.067	0.034	0.076	0.027	0.063	0.042	0.091	0.038	0.093
TAint	0.002	0.018	0.002	0.015	0.002	0.017	0.002	0.013	0.004	0.023	0.004	0.025
Innovative output variables												
TURNIN	0.30	0.29	0.39	0.28	0.30	0.29	0.39	0.27	0.34	0.32	0.44	0.30
PROD (*dummy*)	0.773	0.419	1	0	0.773	0.419	1	0	0.778	0.416	1	0
Firm's general characteristics												
EXPint	0.254	0.285	0.278	0.290	0.259	0.286	0.283	0.290	0.215	0.279	0.235	0.286
IG (*dummy*)	0.291	0.454	0.318	0.466	0.290	0.454	0.318	0.466	0.300	0.459	0.316	0.466
Innovative-relevant information												
SUPPORT (*dummy*)	0.533	0.499	0.539	0.499	0.533	0.499	0.536	0.499	0.536	0.499	0.566	0.497
COOP (*dummy*)	0.161	0.368	0.192	0.394	0.162	0.369	0.193	0.395	0.150	0.358	0.180	0.385
PATENT (*dummy*)	0.348	0.476	0.413	0.492	0.354	0.478	0.420	0.494	0.293	0.456	0.360	0.481
PROT (*dummy*)	0.679	0.467	0.756	0.430	0.683	0.465	0.758	0.428	0.642	0.480	0.737	0.441
HURDLE (*dummy*)	0.402	0.490	0.424	0.494	0.397	0.489	0.418	0.493	0.440	0.497	0.474	0.500
OTHERIN (*dummy*)	0.841	0.365	0.886	0.318	0.838	0.369	0.884	0.320	0.874	0.333	0.899	0.302
Pavitt sectoral dummies												
SB (*dummy*)	0.116	0.320	0.134	0.341	0.113	0.316	0.130	0.337	0.140	0.347	0.167	0.373
SI (*dummy*)	0.284	0.451	0.250	0.433	0.282	0.450	0.248	0.432	0.300	0.459	0.267	0.444
SS (*dummy*)	0.280	0.449	0.314	0.464	0.282	0.450	0.318	0.466	0.266	0.443	0.285	0.452
SD (*dummy*)	0.320	0.466	0.301	0.459	0.323	0.468	0.304	0.460	0.293	0.456	0.281	0.450

Table 3.3. Sectoral composition (2-digit manufacturing sectors) and average employment of the firms belonging to the two subsamples: YICs and mature firms

INDUSTRY	YOUNG			MATURE		
	N. of firms	%	Av. Emp.	N. of firms	%	Av. Emp.
Manufacture of food products and beverage	14	4.8	136	152	6.3	210
Manufacture of textiles	13	4.4	107	110	4.5	205
Manufacture of wearing apparel;	6	2.0	47	43	1.8	131
Manufacture of leather and related products	7	2.4	73	58	2.4	83
Manufacture of wood and of products of wood	9	3.1	26	80	3.3	55
Manufacture of paper and paper products	8	2.7	65	72	3.0	89
Printing and reproduction of recorded media	10	3.4	34	124	5.1	97
Manufacture of coke and refined petroleum products	5	1.7	139	18	0.7	52
Manufacture of chemicals and chemical products	27	9.2	191	200	8.3	189
Manufacture of rubber and plastics products	15	5.1	62	151	6.2	128
Manufacture of other non-metallic mineral products	17	5.8	37	152	6.3	173
Manufacture of basic metals	18	6.1	133	94	3.9	335
Manufacture of fabricated metal products	26	8.9	79	194	8.0	115
Manufacture of machinery and mechanical equipment	37	12.6	197	292	12.1	252
Manufacture of office machinery and computers	7	2.4	26	33	1.4	82
Manufacture of electrical equipment	13	4.4	96	154	6.4	174
Manufacture of radio, television and comm.equipment	9	3.1	277	97	4.0	222
Manufacture of medical, precision and optical instr.	23	7.8	118	126	5.2	75
Manufacture of motor veh., trailers and semi-trailers	11	3.8	77	84	3.5	460
Manufacture of other transport equipment	8	2.7	73	49	2.0	646
Other manufacturing	8	2.7	53	124	5.1	91
Waste collection, treatment and disposal activities;	2	0.7	15	13	0.5	17
PAVITT TAXONOMY						
Science Based	41	14	165.29	273	11.28	296.52
Scale Intensive	88	30.03	95.02	683	28.22	192.74
Specialized Suppliers	78	26.62	131.13	683	28.22	179.43
Suppliers Dominated	86	29.35	87.30	781	32.27	136.77
SAMPLE	293	100	112.20	2,420	100	182.63

Table 3.4. The sample selection estimates. Columns 1-3-5: probit estimates (with marginal effects) of the likelihood of product innovation (selection equation); columns 2-4-6: sample selected estimates of the intensity of product innovation (main equation)

	ALL FIRMS		MATURE FIRMS		YICs	
	PROD (1)	TURNIN (2)	PROD (3)	TURNIN (4)	PROD (5)	TURNIN (6)
Constant		0.16*** (3.01)		0.20*** (3.60)		0.12 (0.85)
IRint	3.84*** (7.59)	1.29*** (4.62)	3.88*** (7.27)	1.28*** (4.29)	3.17** (2.04)	0.80 (1.16)
ERint	1.96 (1.24)	0.26 (0.37)	2.16 (1.25)	-0.01 (-0.02)	0.57 (0.14)	1.36 (0.79)
MACint	-0.28*** (-3.21)	0.32*** (3.07)	-0.35*** (-3.59)	0.27** (2.32)	0.04 (0.20)	0.68*** (3.03)
Taint	-0.08 (-0.20)	-0.35 (-0.87)	-0.06 (-0.15)	-0.69 (-1.47)	-0.20 (-0.21)	0.37 (0.43)
EXPint	0.03 (0.89)	0.03 (1.29)	0.03 (0.93)	0.015 (0.65)	0.01 (0.11)	0.17** (2.14)
IG	0.00 (0.19)		0.00 (0.24)		-0.02 (-0.47)	
SUPPORT	-0.02 (-1.43)		-0.03** (-2.01)		0.09* (1.86)	
COOP	0.08*** (4.14)	0.03* (1.86)	0.08*** (3.95)	0.03* (1.65)	0.09* (1.87)	0.01 (0.25)
PATENT	0.11*** (6.78)		0.11*** (6.35)		0.12** (2.68)	
PROT	0.12*** (6.47)	0.05** (2.41)	0.12*** (5.72)	0.05** (2.11)	0.18*** (3.05)	0.06 (0.75)
HURDLE	-0.01 (-0.09)	-0.02 (-1.60)	-0.01 (-0.34)	-0.03** (-2.11)	0.02 (0.39)	0.02 (0.57)
OTHERIN	0.12*** (4.91)	0.07*** (2.97)	0.13*** (4.96)	0.06** (2.52)	0.04 (0.54)	0.05 (0.76)
SB	0.04 (1.57)	0.08*** (3.67)	0.03 (1.08)	0.06*** (2.63)	0.10 (1.84)	0.20*** (2.81)
SI	-0.02 (-1.18)	-0.00 (-0.06)	-0.02 (-1.11)	0.00 (0.05)	-0.06 (-1.09)	-0.01 (-0.11)
SS	0.08*** (4.80)	0.07*** (4.05)	0.09*** (4.70)	0.07*** (3.53)	0.04 (0.84)	0.07 (1.18)
ρ	0.62		0.48		0.85	
Mills λ	0.18*** (2.98)		0.14** (2.19)		0.27* (1.75)	
N.of firms	2,713	2,098	2,420	1,870	293	228

Notes:- z - statistics in parentheses:*significant at 10%; **5%; ***1%

Table 3.5. The Tobit estimates

	ALL FIRMS	MATURE FIRMS	YICs
Dependent variable: TURNIN			
Constant	0.01	0.02	-0.01
	(0.61)	(0.87)	(-0.15)
IRint	1.94***	2.07***	1.07
	(7.12)	(6.99)	(1.48)
ERint	0.37	0.11	0.97
	(0.47)	(0.12)	(0.50)
MACint	0.01	-0.11	0.63**
	(0.06)	(-1.12)	(2.58)
Taint	-0.34	-0.46	0.26
	(-0.84)	(-1.00)	(0.27)
EXPINT	0.05*	0.04	0.09
	(1.78)	(1.54)	(1.13)
IG	-0.03*	-0.03*	-0.02
	(-1.76)	(-1.82)	(-0.37)
SUPPORT	-0.03**	-0.04***	0.02
	(-2.44)	(-2.74)	(0.38)
COOP	0.06***	0.06***	0.04
	(3.11)	(3.14)	(0.64)
PATENT	0.03**	0.03*	0.09*
	(2.11)	(1.78)	(1.72)
PROT	0.11***	0.11***	0.11**
	(6.74)	(6.41)	(2.17)
HURDLE	-0.02	-0.03*	0.03
	(-1.29)	(-1.72)	(0.67)
OTHERINN	0.13***	0.13***	0.08
	(6.03)	(5.96)	(1.15)
SB	0.09***	0.07***	0.19***
	(3.60)	(2.66)	(2.64)
SI	-0.01	-0.01	-0.03
	(-0.71)	(-0.65)	(-0.44)
SS	0.09***	0.09***	0.08
	(5.24)	(4.94)	(1.32)
N. of firms	2,713	2,420	293
Censored	615	550	65
Uncensored	2,098	1,870	228
Notes t- statistics in parentheses: * Significant at 10%; ** 5%; *** 1%			

Appendix 3

Table A3.1. The questionnaire

Innovative input variables	
Did your enterprise engage in the following innovation activities in 2000?:	
IR: Intramural research & experimental development	All creative work undertaken within your enterprise on a systematic basis in order to increase the stock of knowledge, and the use of this stock of knowledge to devise new applications, such as new and improved products (goods/ services) and processes (including software research)
ER: Acquisition of R&D (extramural R&D)	Same activities as above, but performed by other companies (including other enterprises within the group) or other public or private research organisations
MAC: Acquisition of machinery and equipment	Advanced machinery, computer hardware specifically purchased to implement new or significantly improved products (goods/services) and/or processes
TA: Acquisition of other external knowledge	Purchase of rights to use patents and non-patented inventions, licenses, know-how, trademarks, software and other types of knowledge from others for use in your enterprise's innovations
Innovative output variable: TURNIN	
- Estimate how your turnover in 2000 was distributed between: - New or significantly improved products (goods or services) introduced during the period 1998-2000 - Unchanged or only marginally modified products (goods or services) during the period 1998–2000	
Firm's general characteristics	
IG	▪ Is your enterprise part of an enterprise group?
Innovative-relevant information	
SUPPORT	▪ Did your enterprise receive any public financial support for innovation activities during the period 1998-2000? (from: local or regional authorities; central government; the European Union) ▪ Has your enterprise received funding from the EU's 4th (1994-98) or 5th (1998-2002) Framework Programmes for RTD?
COOP	▪ Did your enterprise have any co-operation arrangements on innovation activities with other enterprises or institutions during 1998-2000?
PATENT	▪ Did your enterprise, or enterprise group, have any valid patents at the end of 2000 protecting inventions or innovations developed by your enterprise?
PROT	▪ During the period 1998-2000, did your enterprise, or enterprise group, make use of any of these other methods to protect inventions or innovations developed in your enterprise? (such as registration of design patterns; trademarks; copyright; secrecy; complexity of design; lead-time advantage on competitors)
OTHERIN	▪ Did your enterprise during the period 1998-2000 undertake any of the following activities?: -Strategy (Implementation of new or significantly changed corporate Strategies) -Management (Implementation of advanced management techniques within your enterprise) -Organisation (Implementation of new or significantly changed organizational structures) -Marketing (Changing significantly your enterprise's marketing concepts/strategies) -Aesthetic change (Significant changes in the aesthetic appearance or design or other subjective changes in at least one of your products)
HURDLE	▪ If your enterprise experienced any hampering factors during the period 1998-2000? Economics factors (excessive perceived economic risks; innovation costs too high; lack of appropriate sources of finance); internal factors (organisational rigidities within the enterprise; lack of qualified personnel; lack of information on technology; lack of information on markets); other factors (insufficient flexibility of regulations or standards; lack of customer responsiveness to new goods or services)

Table A3.2. Correlation matrix (overall sample: 2,713 firms)

	PROD	IRint	ERint	MACint	TAint	EXPint	OTHERIN	IG	SUPPORT	COOP	PATENT	PROT	HURDLE
PROD	1.000												
IRint	0.186	1.000											
ERint	0.093	0.245	1.000										
MACint	-0.159	-0.069	-0.046	1.000									
Taint	-0.007	0.026	0.044	0.034	1.000								
EXPint	0.160	0.050	0.041	-0.167	-0.037	1.000							
OTHERIN	0.223	0.062	0.049	-0.093	0.027	0.163	1.000						
IG	0.110	0.024	0.057	-0.115	-0.008	0.243	0.109	1.000					
SUPPORT	0.021	0.178	0.061	0.060	0.003	0.055	0.031	0.000	1.000				
COOP	0.156	0.173	0.168	-0.074	0.014	0.159	0.105	0.249	0.118	1.000			
PATENT	0.253	0.096	0.102	-0.141	0.020	0.304	0.171	0.241	0.055	0.196	1.000		
PROT	0.306	0.150	0.099	-0.134	-0.003	0.240	0.311	0.185	0.059	0.186	0.370	1.000	
HURDLE	0.083	0.100	0.091	-0.018	0.036	0.048	0.139	0.000	0.002	0.093	0.116	0.152	1.000
SB	0.108	0.234	0.220	-0.054	0.001	0.048	0.059	0.050	0.019	0.127	0.135	0.140	0.051
SI	-0.139	-0.077	-0.090	0.107	0.017	-0.149	-0.073	-0.015	0.008	-0.031	-0.121	-0.126	-0.058
SS	0.138	0.065	0.037	-0.094	-0.024	0.154	0.010	0.041	0.031	0.077	0.114	0.059	0.042
SD	-0.073	-0.149	-0.100	0.024	0.006	-0.038	0.020	-0.059	-0.051	-0.130	-0.086	-0.031	-0.020

Chapter IV
Do different innovative inputs lead to different innovative outputs in mature and young firms?

4.1 Introduction

Historically, technological innovation has been recognised as one of the major source of growth and development (Solow, 1956; Romer, 1986). Recently, thanks also to the increased availability of micro-level data from innovation surveys, we have assisted to a flourishing interest on this subject (see Hall *et al.*, 2010 for a recent review on the subject). Starting from the seminal work of Crepon *et al.* (1998), many researchers have tried to explain economic growth by technological outputs and the latter by technological effort. In general, results have shown a clear-cut positive relationship between R&D and innovation on the one hand, and different measures of economic growth on the other hand.

However, most of these studies have invariably omitted to take into account the high degree of heterogeneity associated with firm innovation. Apart from internal formalised R&D, firms can also rely on different external sources of innovation, like technological acquisition, with particular reference to the part of technological change embodied in the acquired goods (as in the case of acquisition/substitution of machinery and equipment).

In addition, as shown by recent evidence (see Santamaría *et al.*, 2009; Ortega-Argilés *et al.*, 2009 and 2010) specific firm and market characteristics played a vital role in determining different firm's innovative strategies, both in terms of innovative inputs and outputs. Among these peculiarities, firm's size and firm's age can be certainly considered as the most important (Acs and Audretsch, 1987; Audretsch, 1995; Huergo and Jaumandreu, 2004). Traditionally, however, it has been shown more interest in analysing possible differences in the innovative behaviour of small and large firms than of mature and young ones. Nevertheless, young firms in general and innovative young firms in particular, are often seen as key actors in economic growth and job creation (Birch, 1979; Acs and Audretsch, 1990; Brüderl and Preisendorfer, 2000). Foster *et al.* (2001) show that one third to one half of aggregate productivity growth in US manufacturing is directly attributable to creation of new firms, reallocation between firms, and disappearance of unsuccessful ones. Other studies have focalised their attention on the relative position of disadvantage of the European context in creating the necessary condition to the born and growth of the so-called Young Innovative Companies (YICs). In this respect, some evidence suggest that EU start-ups face higher barriers to entry, innovate and growth compared to their US counterparts (see Bartelsmann *et al.* 2004, Philippon and Véron, 2008). Accordingly, in the last few years, several EU member States have been promoting policy intervention aimed at encouraging the establishment, consolidation and development of YICs (Schneider and Veugelers, 2010; Moncada-Paternò-Castello, 2011).

In this line, the aim of this paper is twofold. Firstly, we try to analyse the determinants of the firms' innovative effort (distinguish between R&D and technological acquisitions) and its link with the different outcomes (in terms of product and process innovation) that the same effort produces. Secondly, we try to shed some light on how these particular relationships differ between young and mature incumbent firms.

With this aim, using the third and the fourth waves of the Italian Community Innovation Survey (CIS), we run a recursive model that can be seen as an extension of a Crépon, Duguet and Mairesse's (1998) partial structure model (hereafter CDM model) to analyse these relationships[29]. Apart from the distinction we make among firms of different age, this is one of the first studies to include in a CDM model context technological acquisition (TA) as an additional innovation input besides R&D. Moreover, in contrast with most previous studies using CIS data, we implement an empirical strategy that takes into account the divide between innovative and not innovative firms in order to correct for a well-known problem of sample selection.

Following this introduction, the next section provides a discussion of the theoretical framework on which this work is based. Section 3 outlines the econometric methodology adopted. Section 4 describes the database and the variables used in our analysis. Section 5 discusses our empirical results and, finally, Section 6 highlights our main conclusions.

4.2 The literature

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[29] The lack of data on firms' productivity prevented us from estimating the last equation of the classic CDM model (see next section for a more detailed description of the model).

In his seminal contribution, Griliches (1979) suggests a model of technological change according to which innovative outputs are seen as the product of knowledge generating inputs. More in detail, the author proposes a three equations model in which one of them is a function (the so-called Knowledge Production Function (KPF)) that links a measure of innovative input (namely R&D) with a measure of innovative output (namely Patents)[30].

Following this insight, Crèpon Duget and Mairesse (1998) developed a more comprehensive model based on three distinct, but interrelated relationships: 1) the innovation input linked with its determinants; 2) the KPF that connects innovation input to innovation output; 3) the productivity equation, in which innovative output leads to productivity growth.

These two seminal works have paved the way for the emergence of a relatively recent field of research aimed at analysing the peculiarities of the innovative process (both at macro and micro level) and its contribution to economic growth. In this respect, a distinction has to be made between those studies based on an application of a CDM fully structure model (i.e. that take into account all the three stages of the model) and those based on a CDM partial structure model (i.e. that consider at least one linkage between the three stages). Taking into account our main research aim, this work can be included in the latter category. Accordingly, in this brief survey we will focus on the two first stages of the CDM model, namely, the innovation inputs linked with their determinants, and the KPF.

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[30] The other two equations in the model represent the determinants of R&D investment and the production function (augmented by the innovation term).

Historically, due also to the lack of other measures of innovation, most studies have mainly focused their attention on the determinants of R&D activity, and its link with a measure of innovative output, most notably patents. However, such an approach appears to be oversimplified and too restrictive. In this respect in fact, as Stoneman (1995, p.5f.) suggests, "R&D is not the only source of technological improvement. A firm may generate its own technology through R&D. It may also generate technological advance through learning of various kinds, design, reverse engineering and imitation [….]. New process technologies may also be acquired from the suppliers of capital goods. The relevant importance of these different sources will depend upon the nature of the firm, its industrial sector and its technological base." Moreover, as pointed out by Kleinknecht *et al.* (2002), R&D accounts just for a quarter of the total expense aimed at obtaining product innovation.

Turning the attention to the innovative output measures, as suggested by several studies, patents appear to be a very rough proxy of innovation for different reasons. Firstly, firms generally prefer other ways of protecting their innovation (see Levin *et al.*, 1987). Secondly, firms with different characteristics (i.e. small *vs* large) and operating in different sectors (i.e. high-tech *vs* low-tech) show a different propensity to patent (see Archibugi and Pianta, 1992; Patel and Pavitt, 1993). Finally, patents differ greatly in their importance.

Accordingly, in the recent years, thanks also to the availability of more comprehensive and precise innovation surveys, some authors have tried to extend the classic approach used to study the firms' innovative process including other measures of innovation activities. In this respect a notable example is the work of Conte and Vivarelli (2005) that can be seen as one of the first attempt to extend the classic approach of the KPF by considering, apart from R&D, also the important role played by the technological acquisitions (investment in new machinery and equipment, and external technology incorporated in licences, consultancies, and know-how) and their impact in determining different types of innovative outputs (product and process innovation). They found that R&D is strictly related to product innovation, while technological acquisition is crucial for process innovation. Moreover, their analyses also show that small firms and firms belonging to low-tech sectors are more oriented "to buy" instead of "to make" technology, while large firms and firms operating in the high-tech sectors are much more R&D based. This is in line with Santamaria *et al.* (2009) that find that the impact of non-R&D activities is particularly important in low and medium-tech firms. Similarly, Pellegrino *et al.* (2012), test an augmented KPF trying to detect some differences among firms of different age. The results of their analyses suggest that, although in-house R&D appears to be important in enhancing the propensity to introduce product innovation both in mature and young firms, innovation intensity in the group of young firms is mainly dependent on embodied technical change from external sources.

A common trait of the above-mentioned works is the fact that they focused just on one stage of the CDM model, that is the KPF. If on the one hand, this approach allows testing the relationship between different measures of innovative inputs and outputs at the same time, on the other hand, it completely ignores the process underlying the firm's innovative decision (i.e. the first stage of the CDM model). This aspect, linked to the way in which most of the data on innovation are collected (in particular CIS data) can compromise the reliability of the results[31]. Thus, the trade-off here is between applying an approach that leads to consistent results but that takes into account just one measure of innovative input (mostly R&D; classical CDM model approach), or ignoring possible sample selection problems in favour of a more detailed analysis of the firm's input-output innovative relationship.

Recently, some authors have proposed an approach that takes into account both these aspects. In this respect it is worth mentioning the work of Polder *et al.* (2010). More in detail, they estimate a CDM fully structure model considering two different measures of innovative input (R&D and the amount of investment in Information and communication technology (ICT)) and three different measures of innovative output (product, process and organizational innovation). They find a significant positive effect of ICT on the three measures of innovative output, while R&D turns out to be important only to enhance the propensity to introduce product innovation. On the same line, Hall *et al.* (2012) further extend this approach considering two different measures of organizational innovation (organizational change associated with product and process innovation). Based on a large unbalanced panel of Italian manufacturing firms, they find that both R&D and ICT are important drivers of innovation activity, although R&D appears to be more relevant for product and process innovation.

In the spirit of these contributions, in this work, as previously mentioned, we rely on an extension of a CDM partial structure model including investments in TA as an additional innovation input besides R&D, and two different measures of innovative outputs (product and process innovation). To the best of our knowledge, this is one of

[31] The source of biased stems from a problem of sample selection that arises when the non-innovative firms are exclude from the analyses (for a more articulated discussion see Mairesse and Mohnen, 2010).

the first studies to include in a CDM type-model an indicator of technological acquisition. Moreover, as another important element of novelty, we analyse the existence of possible differences between mature and young firms (see Section 4 for a more precise definition of these two categories) in terms of both drivers of R&D and TA and peculiarities of the KPF. In this respect, no existing literature has provided evidence to these particular research questions. However, some interesting and useful insights can be gained by considering the main results of some recent studies that have looked at the peculiarities of the young companies' innovative process.

Garcia-Quevedo *et al.* (2011), drawing on an unbalanced dataset of more than 2,000 Spanish manufacturing firms, look at the R&D drivers of young and mature firms. The results of their econometric estimations show that different firms and market characteristics play a different role in determining the innovative decisions of mature and young firms. In particular, if on the one hand factors like market concentration and the degree of product diversification are more important in fostering the innovative activity of the mature firms only, on the other hand young firms' spending on R&D seem to be more sensitive to demand pull variables, suggesting the presence of credit constraints for this particular type of firms.

In a very recent study, Criscuolo *et al.*(2012), unlike the above mentioned study, concentrate their attention to the output side of the innovative activity. In particular, using a large sample of UK firms, they try to explore possible differences between start-ups and established firms in terms of innovative performance, looking at both manufacturing and service sectors. They find that being a new firm increase the probability to introduce a radical product or process innovation in the service sector, while in the manufacturing sectors new established firms tend to be less innovative than established firms. This latter result is in line with the previously mentioned study of Pellegrino *et al.* (2012) that, relying on data from the Italian CIS, show that the young innovative companies are less R&D based and perform worse in terms of innovative turnover than their mature counterparts.

4.3 Model and Econometric Methodology

As mentioned in the Introduction, the empirical analyses of this work are carried out by applying an extended version of a classic CDM partial structure model. More in detail, we follow an approach initially proposed by Griffith *et al.* (2006) and subsequently used also by Mairesse and Robin (2009) who enrich the basic CDM model considering as innovative outputs product as well as process innovation[32]. We augment their model including a further equation for technological acquisition. Accordingly, our approach is formalised in 6 equations: (1) the firms' decision to engage in R&D activity; (2) the firm's decision regarding the amount of resources to be invested in R&D activity; (3) the firms' decision to invest in TA; (4) the firm's decision regarding the amount of resources to be invested in TA; (5) – (6) the knowledge production function, in which we consider two different innovative outputs (product and process innovation).

Another important peculiarity of our empirical strategy is that, in contrast to most previous studies, we do not focalise our attention only on the cohort of innovative

[32] Both studies are based on a fully structure CDM model.

firms, but perform our analysis considering the whole sample of firms. In particular, the KPF (steps (v-vi)) is estimated using the predicted values for all firms obtained from the estimations of steps (i) - (iv) that are based on reported R&D and TA figures. This approach reflects the assumption that all the firms exert some effort in innovative activities, although some of them do not report any innovative investment. In this respect, firm' workers may spend a certain amount of their workday trying to find out a more efficient way to carry out the production process in which they are involved. The same process could apply for personnel employed in other firms that provide external technology (investment in new machinery and equipment and purchasing of external technology incorporated in licences, consultancies and know-how). In both cases if the effort does not exceed a certain threshold will not be reported by the firm as investment in R&D activity and TA.

Having delineated the main peculiarities of our empirical strategies, in the following two subsections we fully describe the econometric methodologies and the specifications used for the estimations of the 6 equations of the model.

4.3.1 Innovation inputs: R&D and technological acquisitions

We individuate two different types of innovation inputs: R&D expenditures (both *intramural* and *extramural*) and technological acquisitions (both in their embodied and disembodied component). As it is well known in the empirical literature dealing with CIS survey (see discussion in Section 4), these variables are subject to selectivity: only those firms that have claimed to be involved in product or process innovation (completed/ongoing/abandoned) report data on innovative investments. Furthermore, since that both types of innovative activities can be performed in an informal way these two variables may be also censored. However, as explained in the previous section, if this innovative effort does not reach a certain threshold the firm will not report it as expenditure. Consequently, both the variables are made up of a certain number of zero and missing values. Econometrically, this mixed pattern of zero/missing and positive values naturally leads to a tobit II model (see Amemiya, 1984) defined as follows.

Let i=1,..........,N index firms. The two firm's innovative decisions are defined by the two binary variables RDT_d_i and TAT_d_i that take value 1 when R&D and TA respectively are observed and 0 otherwise. We linked RDT_d_i and TAT_d_i with the two latent variables $RDT\_d_i^*$, $TAT\_d_i^*$ such that:

$$(1) RDT\_d_i = \begin{cases} 1 \text{ when } RDT\_d_i^* = \alpha_1' x_{1i} + \varepsilon_{1i} > 0 \\ 0 \text{ when } RDT\_d_i^* = \alpha_1' x_{1i} + \varepsilon_{1i} \leq 0 \end{cases}$$

and

$$(2) TAT\_d_i = \begin{cases} 1 \; when \;\; TAT\_d_i^* = \alpha_2' x_{2i} + \varepsilon_{2i} > 0 \\ 0 \; when \;\; TAT\_d_i^* = \alpha_2' x_{2i} + \varepsilon_{2i} \leq 0 \end{cases}$$

We indicate with RDT_i the amount of firm's turnover employed as investment in both *intramural* and *extramural* R&D, and with TAT_i the amount of firm's turnover employed as investment in technological acquisitions. Denoting the correspondent latent variables with RDT_i^* and TAT_i^* we have:

$$(3)\mathrm{RDT_i} = \begin{cases} \mathrm{RDT_i^*} = \beta_1' w_{1i} + u_{1i} & \text{when } \mathrm{RDT\_d_i} = 1 \\ 0 & \text{when } \mathrm{RDT\_d_i} = 0 \end{cases}$$

and

$$(4)\mathrm{TAT_i} = \begin{cases} \mathrm{TAT_i^*} = \beta_2' w_{2i} + u_{2i} & \text{when } \mathrm{TAT\_d_i} = 1 \\ 0 & \text{when } \mathrm{TAT\_d_i} = 0 \end{cases}$$

For each firm i, x_j and w_j (with j = {1, 2}) are vectors of explanatory variables some of which could be common to both vectors. Assuming that each pair of error terms ε_1 and u_1, and ε_2 and u_2 is bivariate normally distributed with correlation coefficients $\rho_{\varepsilon 1 u 1}$ and $\rho_{\varepsilon 2 u 2}$, we estimate equations (1) - (3) and (2) - (4) with the Heckman two-step procedure (Heckman, 1979).

Since that our analysis is focused on the whole sample of firms and not only on that of innovative firms, to model the firms' innovative decisions (equations (1) and (2)) we can only use the limited information available for all firms (see next section). Taking into account this important aspect, and bearing in mind the primary objective to make fully comparable the microdata stemming from CIS3 and CIS4 datasets, the choice of the explanatory variables has been made following both the original framework proposed by Crépon *et al.* (1998) and the extensions put forward by Griffith *et al.* (2006) and Mairesse and Robin (2009). For sake of symmetry, we decided to estimate the 2 pair of equations (equations (1)-(3) and (2)-(4)) using the same specifications.

Starting from the selection equations (1) and (2), we use an indicator whether the firm is part of an enterprise group or not, indicator of whether the international market is the firm's most significant market in order to measure the international competition and two indicators of whether the firm makes use respectively of patents and strategic methods (registration of design, trademarks, copyrights) to protect its innovations[33]. Moreover, following the Schumpeterian tradition we include a set of industry dummy variables (based on the 2-digit ateco codes[34]) to capture the market conditions and a variable reporting the log of the total number of employees as measure of firm size.

To model the firms' propensity to invest in R&D and TA (equations (3) and (4)) we can rely on additional information that are available only when firms are innovative and that may be, consequently, useful to characterize the R&D/TA (see discussion in Section 4). Along with the regressors used in the selection equations, in accordance with previous evidence that show the important role of cooperation agreements in affecting the level of investment in innovative activities (Cassiman and Veuglers, 2002; Piga and Vivarelli, 2003, 2004), we also consider a dummy variable that identifies firms that had some cooperative agreements on innovation activities during the three-year period. Moreover, in order to test the supposed positive impact of the public funding in fuelling the firm' innovative activity (see Busom, 2000; Gonzales *et al*., 2005) a binary variable indicating if the firm has received some (local/national/EU) public financial supports for innovative activities is included. In addition, we also consider two binary variables that take on value 1 if the firm has used respectively any type of internal and external sources of information for its innovative activity. In this respect, a recent stream of literature emphasises the important role played by both internal and external sources of

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[33] Previous studies generally show a clear cut positive link between these factors and the firms' innovative activity (see Levin *et al.*, 1987; Salomon and Shaver, 2005; Liu and Buck, 2007; Raymond *et al.* 2009).
[34] The Italian industrial classification (Ateco codes) corresponds, to a large extent, to the European NACE taxonomy.

information in determining the innovative choice of a firm (see Amara and Landry, 2005).

For reasons of identification the employed econometric method requires an exclusion restriction. Accordingly, we decide to exclude from equations (3) and (4) the variable firm size and the variable that indicates if the international market is the firm's most significant market. As for the first variable, the choice was primarily motivated by the fact that the dependent variables, being expressed in intensities, are implicitly scaled for size, and it is further supported by the results of previous studies. In this respect, for example, Griffith *et al.* (2006) find that in several European countries firm size affects significantly the probability to engage in R&D but not the level of R&D investment. Similarly, several contributions have shown a positive and significant causal effect of different indicators of international competition on the firm's probability to innovate but not on the level of investment of R&D activities (see Salomon and Shaver, 2005; Griffith *et al.* 2006; Liu and Buck, 2007).

4.3.2 Innovation outputs: product and process innovation.

In this study, we model the KPF considering two types of innovative outputs, that is process and product innovations. Formally, the following two equations can be written as follows:

$$(5)\ \ PROD_i^* = \alpha_3' \widehat{RDT}_i + \beta_3' \widehat{TAT}_i + \gamma' x_{3i} + \varepsilon_{3i}$$

$$(6)\ PROC_i^* = \alpha_4' \widehat{RDT}_i + \beta_4' \widehat{TAT}_i + \pi' x_{4i} + \varepsilon_{4i}$$

Where $\widehat{RDT}_i$ and $\widehat{TAT}_i$ represent the predictions of the dependent variables of equations (3) and (4) conditional on the firm' decision to engage in innovation activities. Also in this case, we do not observe the level of knowledge generated by the firm, but we only have information on whether the firm has realised product and/or process innovation. Accordingly, if we indicate with $PROD_i$ and $PROC_i$ the two dummy variables that single out the realization of these events we will have:

$$(5a)\ \Pr[PROD_i = 1] = \Pr\left[\alpha'_3\, \widehat{RDT}_i + \beta'_3 \widehat{TAT}_i + \gamma' x_{3i} + \varepsilon_{3i} > 0\right]$$

$$(6a)\ \Pr[PROC_i = 1] = \Pr\left[\alpha'_4\, \widehat{RDT}_i + \beta'_4 \widehat{TAT}_i + \pi' x_{4i} + \varepsilon_{4i} > 0\right]$$

Assuming that the two error terms ε_{3i} and ε_{4i} follow a bivariate normal distribution and that are correlated with correlation coefficient $\rho_{\varepsilon_{34}}$ equation (5) and (6) define a bivariate Probit model, and are jointly estimated by maximum likelihood in Stata.

Apart from firm size (expressed in logarithm) and the set of industry-specific dummies, the vectors γ and π include 2 dummies denoting those firms that have realised managerial, strategic or organisational innovation ('IORG'), and those that have implemented changes in marketing concepts or strategies ('IMARK'). In this respect, the occurrence of other forms of innovation should be complementary to the two innovative inputs considered in the specification (see Bresnahan *et al.*, 2002; Hitt and Brynjolfsson, 2002; Piva *et al.*, 2005).

As already stated, by using the predictions for innovation inputs instead of the reported values we are able to estimate the knowledge production function using the whole sample. In this way, the number of observations is increased and the selectivity bias is avoided. Moreover, as long as the variables in equations (1)-(3) and (2)-(4) are exogenous, such approach allows us to control for possible endogeneity of the innovative inputs. In this respect, it is very likely that unobservable characteristics included in the error terms ε_{3i} and ε_{4i} are important in increasing both the firms' innovative effort and the firms' propensity to introduce new innovations. This would cause an upward biased estimate of the parameters α_3, β_3 and α_4, β_4 because of their positive correlation with ε_{3i} and ε_{4i} respectively.

4.4 Data

This work uses firm-level data drawn from the third and fourth (CIS3 and CIS4) waves of the Italian CIS. The CIS is a harmonized survey that is carried out by national statistical agencies (ISTAT in Italy) in all the 27 EU member States under the coordination of Eurostat. CIS3 was conducted in 2001 and provides information for the three-year period 1998-2000, while CIS4 was conducted in 2005 and provides information for the three-year period 2002-2004. These surveys are representative at both sector and firm size level of the entire population of Italian firms with more than 10 employees. In conducting the surveys, ISTAT adopts a weighting procedure that relates the sample of firms interviewed to the entire population[35] (ISTAT, 2004).

[35] Firm selection was carried out through a 'one step stratified sample design'. The sample in each stratum was selected with equal probability and without reimmission. The stratification of the sample was based on the following three variables: firm size, sector, regional location.

As previously mentioned, the way in which the Italian CIS questionnaire is structured allows us to have only a limited amount of information regarding all the interviewed firms. In particular, all firms are requested to answer to some questions providing general information, such as the number of employees, the main industry of affiliation, the belonging to a group and whether they have innovation activities (completed/ongoing/abandoned) or not. Only those firms that declare to be innovative are asked to answer to a much larger set of additional questions on the firms' innovativeness, the effects of innovation, participation in cooperative innovation activities and access to public funding, among the others. Most of these information are available in both datasets, although some differences between the two questionnaires can be detected. More in detail, with respect to the variables that we have used for the estimations, while CIS3 gathers several information regarding the formal methods of protection for innovation, CIS4 provides information only on whether a firm has applied or not for a patent.

The original CIS3 and CIS4 database were made up of respectively 15,512 (CIS3) and 21,854 (CIS4) firms operating in all the sectors of economy. After dropping those firms not operating in the manufacturing sectors, those that employ more than

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Technically, in the generic stratum h, the random selection of n_{h} sample observations among the N_{h} belonging to the entire population was realized through the following procedure:
- a random number in the 0-1 interval was attributed to each N_h population unit;
- N_h population units were sorted by increasing values of the random number;
- units in the first n_h positions in the order previously mentioned were selected.
Estimates obtained from the selected sample are very close to the actual values in the national population. The weighting procedure follows Eurostat and Oslo Manual (OECD, 1997) recommendations: weights indicate the inverse of the probability that the observation is sampled. Therefore, sampling weights ensure that each group of firms is properly represented and correct for sample selection. Moreover, sampling weights help in reducing heteroskedasticity commonly arising when the analysis focuses on survey data. It is important to note that this sample weighting was carried out *ex-ante* by ISTAT in the process of providing the original data, therefore it is not implying any cleaning procedure by the authors.

5,000 employees and that state a level of R&D expenditures and/or TA higher than 50% of the total turnover we ended up with 7,185 (CIS3) and 7,329 (CIS4) innovating and not-innovating firms.

According to the particular aim of this paper it has been necessary to single out a given age threshold in order to select from the total samples the two sub-samples of young and mature firms. In line with previous works (see Garcia-Quevedo *et al.* 2011 and Pellegrino *et al.* 2012) and following the general criteria that the European Commission used to single out the YICs, we opted for 8 years threshold[36]. Table 4.1 shows the sectoral composition of the total sample distinguish between young and mature firms. The overall impression is that no striking differences emerge with respect to the distribution among the various samples (both total samples and sub-sample of young and mature firms) across the different industries categories[37]. As far as size is concerned, young firms in CIS3 appear to be much smaller than both their mature counterparts (56 *vs* 90 employees on average), and the group of young firms in CIS4 (56 *vs* 98 employees on average).

< INSERT TABLE 4.1 >

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[36] According to the European Commission's State Aid rules, Young Innovative Companies are defined, among other requirements, as companies with less than 6 years. However some European countries in adopting the European Directive have extended this threshold (i.e. 8 years for France and Estonia). The choice of 8 years allows us to reach a good degree of representativeness of the sub-sample of young firms, without increasing the age threshold too much. However we performed several robustness checks, assuming the alternative thresholds of 6, 7, 9 and 10 years; results – available upon request – are consistent, both in terms of sign and statistical significance of the estimated coefficients, with those discussed in Section 5.

[37] To aggregate the industry categories, based on the 2-digit NACE classification, we follow Griffith *et al.*(2006)

This aspect, due to the different composition of the two datasets, does not affect the reliability of the econometric estimations[38].

Table 4.2 gives the summary statistics (mean and standard deviation) for the dependent variables and the regressors used in the model (see table A4.1 in the appendix for a detailed definition of the variables). Also in this case, CIS3 and CIS4 samples look very similar in average, the only notable difference being in the higher percentage of CIS3's firms introducing product innovation (28% *vs* 19%). However looking at the two sub-samples of young and mature firms, more evident differences can be detected. In particular, young firms appear to be less innovative with respect both the intensity of the innovative effort and the capacity to realise process and product innovations. Furthermore, it seems that the use of appropriability means (both formal and strategic) increase with age, as well as the degree of international market exposure.

< INSERT TABLE 4.2 >

4.5 Results

In the following two sub-sections we comment the estimation results of the 6 equations model outlined in Section 3. More in detail for each step of the model we present the results for the entire samples (CIS3 and CIS4) and for the four sub-samples

[38] Robustness checks were performed used a CIS4 sample cleaned by potential outliers as far as young firms are concerned. The results –available upon request– are in line (both in terms of sign and statistical significance) with those discussed in Section 5.

of mature incumbents and young firms. Accordingly, in discussing the results, we will consider possible differences both among sub-samples of firms belonging to different datasets and between mature and young firms belonging to the same dataset.

Before moving to the discussion, it is important to note that our estimations are based on cross-sectional data, and most of the regressors used are simultaneously determined. Bearing in mind this important caveat, the interpretation of the results has to be done with caution.

4.5.1 Innovation inputs

Tables 4.3 and 4.4 show the estimation results for respectively the R&D – (1) and (3) –, and TA – (2) and (4) – equations. We first concentrate our attention on possible differences regarding the role played by factors in determining the innovate choice (R&D and TA) of the firms both in terms of whether or not to engage in innovative activities and how intensively invest in the same innovative activities. More in detail, we will look at the results of the selection and main equations for the two different innovative inputs (R&D and TA) concentrating the attention only to the total samples of the two datasets (columns 1 – 2 and 7 – 8 in table 4.3 and 4.4).

A first notable result is that, in general, the sign and the significance of the coefficients are quite similar across the two different datasets. This means that our results are robust across different samples of firms over different time periods. If we compare the results of the two input equations, the most evident difference is related to the level of significance of the variable 'COOP'. Indeed, it appears that those firms that take part into cooperative activities are more likely to increase the intensity of their investment in R&D activities but not in TA. This result could reflect the vital role played by some cooperation partner (in particular universities, private and public research institutes) in determining the firm' R&D effort. Apart from this result, no other relevant differences can be detected between the two equations. In particular, looking at the other factors that are exclusively included in the level equations, the use of any type of sources of information to innovation (both internal and external) turns out to be insignificant in determining the firms' level of investment in both innovative inputs categories. On the contrary, there appears that those firms that benefit from any type of support to their innovation activities are more likely to spend more on R&D and TA.

As for the factors included in both selection and level equations, we can see that being part of a group does not seem to be an important driver of neither R&D nor TA activities. Indeed, the coefficients of the variable 'IG', with the exception of the R&D selection equation refers to the CIS4 (column 7 in table 4.3) turns out to be insignificant in all the models. On the contrary, those firms that have made use of appropriability means (both formal and strategic), seem to have more chance to engage in both types of innovative activities. Moreover, the formal methods to appropriability (variable 'PATDEP') appear to have an important role also in enhancing the level of investment in both R&D and TA.

Finally, looking at those variables included only in the selection equations, we can see that larger firms, and firms that are more oriented towards international markets are also more likely to engage in both innovation activities.

We now move to the comparison between mature and young firms. In particular, we will describe the estimations results of the remaining columns (3 – 4 – 5 – 6 – 9 – 10 – 11 and 12) in tables 4.3 and 4.4.

Firstly, also in this case, with the exception of some slight differences (i.e. variable 'COOP' in the R&D equation significant for the sample of CIS4 young firms but not for their CIS3 counterparts), the results are pretty much consistent across the different samples/sub-sample of firms over different time periods. Moreover, looking at the two different sub-samples of mature and young firms, some results are in line with those regarding the total samples. More in particular, the variable 'IG', with the exception of the selection equation in CIS4 (where the coefficient is positive and slightly significant), does not affect the two different firm innovative decisions. Furthermore, firm size and the international market exposure appear to be important factors in boosting the firm's probability to engage in both R&D and TA, regardless the age of the firms[39]. In addition, both mature and young firms (even if this evidence is stronger for mature firms) that cooperate on innovation activity are likely to spend more on R&D but not on TA. Moreover, in line with the previously discussed results, the variable 'SUPPORT' appears to play an important role in determining the level of R&D investment in both sub-sample and for both datasets. However, this variable turns out to be still highly significant in the TA equations, for sample of mature firms only. This result, which holds across the two different datasets, could suggest the need to design different policy measurers to support different innovative activities (R&D *vs* TA) of different cohorts of firms (mature *vs* young). Another important difference in terms of relevance of innovative drivers between the two sub-samples is related to the sign and significance of the two dummy variables denoting those firms that make use of any type of internal and external sources of information for innovation activities. Looking at the

[39] The only result that appears in contrast regards the insignificance of the variable EXP_d in the TA equation for the sample of young firms belonging to CIS3.

R&D equation, in fact, in both the dataset the role of the variable 'INFO_IN' is highly important in boosting the intensity of the investment of young firms, but appears not relevant in the case of mature firms. As for the variable identifying those firms that make use of external sources of information for their innovation activities, as can be seen from table 4.3, young firms in CIS3, in contrast to their mature counterparts, seem to be negatively affected by this factor with respect to their R&D intensity decision. Instead, turning the attention to the TA equation (table 4.4), this variable appears to significantly increase the level of investment in TA among young firms, but not among mature ones[40]. All in all, these important evidence suggest that: 1) young firms tend to show an higher level of sensitivity to the different sources of information to innovation with respect to their mature counterparts when they have to decide how much invest in innovative activities (both R&D and TA); 2) different sources of information (internal *vs* external) have a distinct impact in determining the level of investment in R&D and TA as far as young firms are concerned.

Finally, as for the means of appropriability, if the variable 'PROT' (strategic method of protection) have almost no impact on the amount of firm's innovative investments, the use of formal methods of protection (variable 'PATDEP') turns out to be highly significant in both main equations and across the two datasets for the mature firms only.

Both the high values of the correlation coefficients (Rho) between the selection and the main equations and the statistical significance of the Lambda Mills ratio in 11 out of 12 models (see lower part of Table 4.3 and 4.4) confirm the validity of the choice of this Heckman-Type specification.

[40] This result holds true only with reference to CIS3.

< INSERT TABLE 4.3 AND 4.4 >

4.5.2 Innovation outputs

Table 4.5 reports the econometric results of the KPF considering both product and process innovation. More in detail, as for the two input equations we report the results for the three different samples (total, mature and young) for both CIS3 (first 6 columns) and CIS4 datasets (last 6 columns). The numbers reported are marginal effects evaluated at the sample means. The use of predicted variables ($\widehat{TAT}$ and $\widehat{RDT}$) as regressors makes the usual standard errors invalid. Accordingly, in table 4.5 we report the t-statistics calculated using the bootstrapped standard errors that appears to be larger than the usual ones.

Following the structure of the previous subsection, we first concentrate the attention on the general results (total samples) and then on possible differences between mature and young firms.

The first important result is that, in line with most of the related literature (see Section 2), R&D appears to be more important for product innovation than for process innovation. This result is particularly evident with respect to CIS4. As can be seen in fact (columns 7 – 8), the effect of the variable $\widehat{RDT}$ is highly significant for product innovation and insignificant for process innovation. Instead, this evidence in less clear in CIS3 where the impact of the variable is equally statistically significant for both innovative outputs. However, as can be seen, the magnitude of its effect is much stronger on product than on process innovation (0.81*vs* 0.33).

On the other hand, investment in TA is important for both types of innovation and in both CIS3 and CIS4 samples, the variable $\widehat{TAT}$ being always highly significant. However, looking at the magnitude of marginal effects, we can see that this particular innovative input appears to be more important for process innovation.

Briefly looking at the other results, we notice that the two dummies variables ('IORG' and 'IMARK') identifying those firms that have realised 'wider' innovation activities, turn out to be always positive and significant, with the variable 'IMARK' appearing more important for product innovation. This result is in line with our expectations, since that the implementation of the marketing concepts is more related to the realisation of product innovation than process innovation.

Finally, the sign and the level of significance of the marginal effects of the variable 'LSIZE' suggest us that larger firms are more likely to engage in both product and process innovations.

Turning our attention to the 4 sub-samples of young and mature firms, the overall impression is that the estimates results are pretty much in line with those previously discussed for both groups of firms. The only notable evidence is represented by the fact that the variable $\widehat{RDT}$ in one case (CIS4 dataset) is important in increasing the likelihood of process innovation for the young firms only. This result could be related to the fact that young firms, being less experienced than their mature counterparts and possibly less specialised with respect to their innovative process, are more able to exploit the interaction between different innovative inputs to pursue at the same time the realisation of different innovative outputs. However, this speculation is not fully supported by our results, since the evidence on which is based does not hold true for the CIS3 dataset. In this case, in fact the variable $\widehat{\text{RDT}}$ appears to be highly significant for both mature and young firms.

As far as the impact of the variable $\widehat{\text{TAT}}$ is concerned, looking at the estimation results, it is quite evident that the level of investment in TA is equally important for both types of innovations without any particular difference between mature and young firms. Again the impact of this variable appears to be more important in determining the realisation of process innovations, and this is particularly evident with respect to the CIS4 sample. Similarly, the marginal effects and the level of significance of the remaining variables ('IORG', 'IMARK' and 'LSIZE') are in line with those of the total sample. Also in this case, for both young and mature firms the realisation of changes in marketing or strategies (variable 'IMARK') is more important for product than for process innovation.

Finally, from the lower part of table 4.5 emerge clearly that the two equations are always highly correlated via the errors terms, the level of the rho ranging between 0.46 and 0.74. This aspect, which suggests the existence of a certain degree of complementarities between the two firms' innovative outputs supports the adoption of a Biprobit model.

< INSERT TABLE 4.5 >

4.6 Conclusion

Based on an extension of a traditional partial structure CDM model, this paper has analysed the determinants of the firms' innovative effort and the results of this effort in terms of innovative outputs by looking at R&D/TA and PROC/PROD and by distinguishing between mature and young firms. Using data from the third and fourth Italian Community Innovation Survey we estimate a structural model that allows for the fact that some firms may undertake innovation but do not report it as R&D and/or TA. We find some interesting results that are robust across different samples of firms over different time periods:

1) Looking at the impact of the different drivers in determining the firms' decision to innovate or not in R&D and TA, no particular differences between mature and young firms can be detected. More in detail, apart from the variable denoting those firms that belong to an industrial group, all the other factors (appropriability conditions, international market exposure and size) turn out to be important in increasing the probability to invest both in R&D and TA for both sub-samples of firms.
2) Different firm and market characteristics have a different impact in affecting the level of investment in R&D/TA both in general and for mature and young firms. In this respect, if the variable SUPPORT plays an important role in increasing the level of investment in R&D in both sub-samples and for both datasets, in the TA equation this variable turns out to be still highly significant only for the group of mature firms. Another important result is related to the fact that young firms show a higher level of sensitivity to the

internal and external sources of innovation with respect to their mature counterparts when they have to decide how much invest in the two innovative inputs. Moreover, it seems that these two different sources of information have a distinct impact in determining the level of investment in R&D and TA as far as young firms are concerned. Finally, the variable that indicate the use of formal methods of protection of innovation activities turns out to be highly significant in both R&D and TA equations and across the two datasets for the mature firms only.

3) No particular differences between young and mature firms emerge in the KPF. Although R&D and TA appear to be both important in increasing the likelihood to introduce both product and process innovation, looking at the marginal effects, there appears that R&D is more linked to product innovation, while TA with process innovation.

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Table 4.1. Sectoral composition (2-digit manufacturing sectors) and average employment; all firms - mature firms; young firms (CIS3 - CIS4)

	CIS3						CIS4					
	TOT		MATURE		YOUNG		TOT		MATURE		YOUNG	
	N	%	N	%	N	%	N	%	N	%	N	%
Food	492	6.9	446	7.2	46	4.9	638	8.7	550	9.2	88	6.6
Textile	1,191	16.6	995	16.0	196	20.7	1,172	16.0	895	15.0	277	20.7
Wood/Paper	986	13.7	882	14.1	104	11.0	907	12.4	756	12.6	151	11.3
Chemicals	494	6.9	435	7.0	59	6.2	460	6.3	382	6.4	78	5.8
Plastic/Rubber	415	5.8	361	5.8	54	5.7	310	4.2	266	4.4	44	3.3
Non-metallic Min.	471	6.6	414	6.6	57	6.0	504	6.9	432	7.2	72	5.4
Basic metals	853	11.9	741	11.9	112	11.8	1,306	17.8	1,054	17.6	252	18.8
Machinery	551	7.7	483	7.8	68	7.2	566	7.7	472	7.9	94	7.0
Electrical	826	11.5	700	11.2	126	13.3	671	9.2	544	9.1	127	9.5
Vehicles	395	5.5	325	5.2	70	7.4	364	5.0	286	4.8	78	5.8
Misc.	511	7.1	454	7.3	57	6.0	431	5.9	351	5.9	80	6.0
Total	7,185	100	6,236	100	949	100	7,329	100	5,988	100	1,341	100
Av. Emp.	85		90		56		102		102		98	

Table 4.2. Descriptive statistics: mean and standard deviation of the variables; all firms-mature firms- young firms (CIS3 –CIS4)

	CIS3			CIS4		
	TOT	MATURE	YOUNG	TOT	MATURE	YOUNG
RDT_d	0.21	0.22	0.15	0.25	0.26	0.22
	(0.41)	(0.41)	(0.36)	(0.44)	(0.44)	(0.41)
RDT	0.048	0.049	0.041	0.066	0.067	0.061
	(1.78)	(1.79)	(1.75)	(2.42)	(2.43)	(2.36)
TAT_d	0.29	0.30	0.21	0.34	0.34	0.30
	(0.45)	(0.46)	(0.41)	(0.47)	(0.47)	(0.46)
TAT	0.011	0.011	0.011	0.012	0.012	0.013
	(3.70)	(3.63)	(4.15)	(3.76)	(3.67)	(4.13)
PROD	0.28	0.29	0.23	0.19	0.19	0.17
	(0.45)	(0.45)	(0.42)	(0.39)	(0.40)	(0.38)
PROC	0.29	0.30	0.25	0.30	0.31	0.28
	(0.45)	(0.46)	(0.43)	(0.46)	(0.46)	(0.45)
IG	0.18	0.18	0.17	0.23	0.23	0.23
	(0.38)	(0.39)	(0.37)	(0.42)	(0.42)	(0.42)
PATDEP	0.12	0.12	0.08	0.12	0.12	0.09
	(0.32)	(0.33)	(0.27)	(0.32)	(0.33)	(0.29)
PROT	0.21	0.22	0.15	0.18	0.19	0.15
	(0.41)	(0.41)	(0.35)	(0.39)	(0.39)	(0.36)
COOP	0.05	0.06	0.04	0.06	0.06	0.06
	(0.23)	(0.23)	(0.19)	(0.24)	(0.24)	(0.24)
SUPPORT	0.20	0.21	0.16	0.18	0.18	0.15
	(0.40)	(0.40)	(0.36)	(0.38)	(0.39)	(0.36)
INFO_IN	0.13	0.13	0.09	0.14	0.14	0.12
	(0.33)	(0.34)	(0.29)	(0.35)	(0.35)	(0.33)
INFO_EX	0.18	0.19	0.13	0.20	0.20	0.19
	(0.38)	(0.39)	(0.33)	(0.40)	(0.40)	(0.39)
EXP_d	0.66	0.68	0.58	0.53	0.55	0.43
	(0.47)	(0.47)	(0.49)	(0.50)	(0.50)	(0.50)
LSIZE	3.64	3.69	3.33	3.67	3.71	3.50
	(1.09)	(1.10)	(0.94)	(1.15)	(1.15)	(1.15)
IORG	0.47	0.47	0.45	0.35	0.35	0.34
	(0.50)	(0.50)	(0.50)	(0.48)	(0.48)	(0.47)
IMARK	0.47	0.47	0.42	0.21	0.22	0.20
	(0.50)	(0.50)	(0.49)	(0.41)	(0.41)	(0.40)
Obs	7,185	6,239	949	7,329	5,988	1,341

Standard deviation in brackets

Table 4.3. Estimation results for the R&D equations (CIS3 - CIS4)

	CIS3						CIS4					
	TOT		MATURE		YOUNG		TOT		MATURE		YOUNG	
Dep. Var.	RDT_d	RDT	RDT_d	RDT	RDT_d	RDT	RDT_d	RDT	RDT_d	RDT	RDT_d	RDT
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
IG	0.04	-0.02	0.03	0.02	0.16	-0.61	0.13***	-0.03	0.12**	-0.16	0.21*	0.62
	(0.78)	(-0.08)	(0.48)	(0.09)	(1.01)	(-0.76)	(2.83)	(-0.12)	(2.28)	(-0.64)	(1.68)	(0.98)
PATDEP	0.70***	1.08***	0.67***	1.00***	0.95***	1.04	0.73***	1.51***	0.66***	1.47***	1.17***	1.20
	(11.23)	(3.93)	(10.32)	(3.56)	(4.27)	(0.92)	(12.55)	(4.72)	(10.63)	(4.37)	(7.17)	(1.31)
PROT	0.35***	0.39*	0.35***	0.42*	0.34*	-0.08	0.29***	0.46*	0.30***	0.32	0.27**	1.26*
	(6.77)	(1.69)	(6.42)	(1.77)	(1.84)	(-0.09)	(6.04)	(1.87)	(5.61)	(1.23)	(2.08)	(1.94)
COOP		0.86***		0.94***		-0.07		1.16***		0.90***		2.37***
		(4.18)		(4.42)		(-0.10)		(4.98)		(3.57)		(4.13)
SUPPORT		1.26***		1.12***		2.91***		0.90***		0.76***		1.43***
		(7.92)		(6.72)		(5.23)		(4.82)		(3.79)		(3.17)
INFO_IN		0.19		0.08		1.61***		0.25		0.05		1.09**
		(1.16)		(0.48)		(2.79)		(1.32)		(0.25)		(2.43)
INFO_EX		0.06		0.15		-1.15**		-0.05		-0.01		-0.53
		(0.36)		(0.87)		(-2.07)		(-0.30)		(-0.05)		(-1.16)
EXP_d	0.41***		0.42***		0.30**		0.48***		0.47***		0.55***	
	(7.90)		(7.56)		(2.21)		(11.94)		(10.57)		(5.52)	
LSIZE	0.33***		0.33***		0.29***		0.23***		0.24***		0.20***	
	(15.45)		(14.67)		(4.39)		(12.07)		(11.33)		(4.22)	
_cons	-2.73***	-3.00***	-2.83***	-2.93***	-2.02***	-2.32	-2.21***	-2.78***	-2.23***	-2.16***	-2.16***	-4.77**
	(-24.97)	(-4.64)	(-23.89)	(-4.30)	(-6.62)	(-1.18)	(-24.12)	(-3.77)	(-22.28)	(-2.73)	(-9.10)	(-2.57)
Lambda	2.34***		2.29***		1.84		2.20***		1.90***		3.20***	
	(7.09)		(6.66)		(1.51)		(5.46)		(4.34)		(3.34)	
Rho	0.66		0.66		0.57		0.52		0.46		0.73	
N	7,185	1,513	6,236	1,366	949	147	7,329	1,859	5,988	1,565	1,341	294

t- statistics in brackets: * Significant at 10%; **5%;***1%. All regressions include industry dummies (results available upon request).

Table 4.4. Estimation results for the Technological Acquisitions equations (CIS3- CIS4)

	CIS3						CIS4					
	TOT		MATURE		YOUNG		TOT		MATURE		YOUNG	
Dep. Var.	TAT_d	TAT	TAT_d	TAT	TAT_d	TAT	TAT_d	TAT	TAT_d	TAT	TAT_d	TAT
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
IG	-0.05	-0.43	-0.06	-0.35	0.05	-0.42	0.07	0.17	0.07	-0.01	0.05	0.60
	(-1.04)	(-1.20)	(-1.17)	(-0.94)	(0.34)	(-0.26)	(1.49)	(0.50)	(1.42)	(-0.04)	(0.45)	(0.59)
PATDEP	0.45***	1.23**	0.41***	1.20**	0.88***	2.25	0.42***	1.49***	0.37***	1.20***	0.71***	3.05*
	(7.53)	(2.39)	(6.55)	(2.38)	(4.12)	(0.69)	(7.51)	(3.24)	(6.15)	(2.63)	(4.70)	(1.86)
PROT	0.34***	0.32	0.37***	0.38	-0.01	-0.19	0.32***	0.97**	0.32***	0.87**	0.30**	0.56
	(7.21)	(0.72)	(7.44)	(0.83)	(-0.03)	(-0.10)	(7.05)	(2.45)	(6.51)	(2.16)	(2.53)	(0.44)
COOP		-0.02		0.04		-1.05		-0.07		-0.35		1.27
		(-0.05)		(0.10)		(-0.59)		(-0.22)		(-1.01)		(1.35)
SUPPORT		0.97***		1.14***		-0.59		1.18***		1.24***		0.82
		(3.81)		(4.42)		(-0.56)		(5.27)		(5.21)		(1.34)
INFO_IN		0.12		0.26		-1.11		0.31		0.16		0.64
		(0.41)		(0.89)		(-0.93)		(1.32)		(0.65)		(1.01)
INFO_EX		0.18		-0.03		2.29**		0.13		0.09		0.33
		(0.68)		(-0.13)		(2.10)		(0.58)		(0.40)		(0.55)
EXP	0.16***		0.16***		0.17		0.36***		0.35***		0.44***	
	(4.00)		(3.60)		(1.58)		(10.08)		(8.77)		(5.07)	
LSIZE	0.24***		0.24***		0.18***		0.16***		0.17***		0.11***	
	(12.52)		(11.85)		(3.02)		(8.88)		(8.64)		(2.58)	
_cons	-1.68***	-2.47**	-1.70***	-2.19*	-1.39***	-6.58	-1.46***	-4.91***	-1.48***	-3.40***	-1.43***	-10.67***
	(-18.52)	(-2.02)	(-17.56)	(-1.77)	(-5.02)	(-1.11)	(-18.02)	(-4.41)	(-16.74)	(-3.02)	(-6.80)	(-2.99)
Lambda	5.34***		5.21***		7.14*		6.42***		5.42***		9.58***	
	(6.42)		(6.15)		(1.77)		(8.53)		(7.02)		(4.31)	
Rho	0.74		0.75		0.78		0.85		0.79		0.98	
N	7,185	2,080	6,236	1,880	949	200	7,329	2,458	5,988	2,054	1,341	937

t- statistics in brackets: * Significant at 10%; **5%;***1%. All regressions include industry dummies (results available upon request).

Table 4.5. Knowledge Production Function: Product and Process Innovation (CIS3 - CIS 4)

	CIS3						CIS4					
	TOT		MATURE		YOUNG		TOT		MATURE		YOUNG	
Dep. Var.	PROD	PROC	PROD	PROC	PROD	PROC	PROD	PROC	PROD	PROC	PROD	PROC
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$\widehat{RDT}$	0.81***	0.33***	0.83***	0.35***	0.54***	0.30***	0.41***	0.02	0.42***	0.05	0.46***	0.20**
	(9.11)	(5.93)	(8.41)	(6.80)	(3.55)	(3.03)	(7.82)	(0.40)	(7.57)	(1.14)	(3.77)	(2.02)
$\widehat{TAT}$	0.79***	0.84***	0.73***	0.77***	0.32**	0.37***	0.98***	1.27***	0.86***	1.09***	0.42**	0.56***
	(9.09)	(11.33)	(9.22)	(11.22)	(2.28)	(3.11)	(11.52)	(14.61)	(9.81)	(15.46)	(2.43)	(4.16)
IORG	0.37***	0.45***	0.38***	0.44***	0.34**	0.52***	0.34***	0.47***	0.34***	0.47***	0.41***	0.56***
	(8.79)	(11.35)	(8.94)	(10.23)	(2.25)	(4.11)	(8.52)	(14.60)	(7.12)	(11.14)	(3.24)	(5.59)
IMARK	0.63***	0.25***	0.62***	0.24***	0.83***	0.37***	0.61***	0.34***	0.60***	0.33***	0.74***	0.47***
	(13.85)	(6.81)	(12.88)	(5.28)	(6.28)	(3.03)	(14.68)	(8.14)	(10.28)	(7.44)	(5.29)	(3.97)
LSIZE	0.18***	0.17***	0.17***	0.16***	0.22***	0.16**	0.27***	0.27***	0.24***	0.22***	0.27***	0.26***
	(9.06)	(8.44)	(7.73)	(8.81)	(2.70)	(2.28)	(14.07)	(15.93)	(10.24)	(12.77)	(4.79)	(5.97)
_cons	-3.00***	-2.60***	-2.91***	-2.53***	-2.55***	-1.89***	-3.57***	-3.01***	-3.40***	-2.76***	-3.07***	-2.44***
	(-19.93)	(-17.90)	(-21.25)	(-19.91)	(-8.55)	(-6.29)	(-23.39)	(-29.44)	(-20.63)	(-24.46)	(-9.20)	(-10.11)
Rho	0.62		0.61		0.74		0.46		0.47		0.54	
N	7,185		6,236		949		7,329		5,988		1,341	

t- statistics in brackets: * Significant at 10%; **5%;***1%. All regressions include industries dummies (results available upon request).

Appendix 4

Table A4.1. The variables: acronyms and definition

Innovative input variables	
RDT_d	Dummy = 1 if firm's R&D expenditures (both intramural and extramural) are positive
RDT	Total firm's R&D expenditures (both intramural and extramural), normalized by total turnover
TAT_d	Dummy = 1 if firm's expenditures for Technological acquisitions (investment in new machinery and equipment and purchasing of external technology incorporated in licences, consultancies and know-how) are positive
TAT	Total firm's expenditures for technological acquisitions, normalized by total turnover
Innovative output variables	
PROD	Dummy = 1 if the firm has introduced new or significantly improved products
PROC	Dummy = 1 if the firm has introduced new or significantly improved processes
Firm's general characteristics	
IG	Dummy = 1 if the firm belongs to an industrial group
Innovative-relevant information	
PATDEP	Dummy = 1 if the firm have applied for patents
PROT	Dummy = 1 if the firm adopts other instruments of protection of innovation activities than patents (trademarks, copyright, registration of design)
COOP	Dummy = 1 if the firm takes part into cooperative innovative activities
SUPPORT	Dummy = 1 if the firm has received public support for innovation
INFO_IN	Dummy = 1 if the firm has used any type of internal source of information for its innovation activities
INFO_EX	Dummy = 1 if the firm has used any type of external source of information for its innovation activities
EXP_d	Dummy =1 if the firm have traded in an international market during the three year period; 0 otherwise
LSIZE	Log of the total number of firms' employees
IORG	Dummy = 1 if the firm has realized managerial, strategic or organizational innovation
IMARK	Dummy = 1 if the firm has implemented changes in marketing concepts or strategies (e.g. packaging or presentational changes to a product to target new markets)

Table A4.2. Correlation matrix (CIS3; overall sample:7,185 firms)

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	RDT_d	1																
(2)	RDT	0.52	1															
(3)	TAT_d	0.49	0.22	1														
(4)	TAT	0.09	0.05	0.47	1													
(5)	PROD	0.63	0.34	0.57	0.19	1												
(6)	PROC	0.44	0.19	0.70	0.38	0.52	1											
(7)	IG	0.25	0.09	0.16	-0.01	0.21	0.14	1										
(8)	PATDEP	0.40	0.20	0.27	0.02	0.37	0.21	0.25	1									
(9)	PROT	0.33	0.14	0.25	0.01	0.32	0.19	0.24	0.55	1								
(10)	COOP	0.36	0.25	0.26	0.06	0.31	0.24	0.23	0.24	0.18	1							
(11)	SUPPORT	0.49	0.34	0.51	0.27	0.46	0.49	0.13	0.25	0.20	0.27	1						
(12)	INFO_IN	0.42	0.25	0.35	0.13	0.39	0.36	0.16	0.22	0.19	0.19	0.34	1					
(13)	INFO_EX	0.44	0.24	0.47	0.20	0.48	0.46	0.17	0.24	0.20	0.25	0.39	0.45	1				
(14)	EXP_d	0.25	0.13	0.17	0.00	0.23	0.14	0.22	0.21	0.27	0.13	0.15	0.14	0.16	1			
(15)	LSIZE	0.38	0.11	0.28	0.01	0.29	0.24	0.51	0.34	0.34	0.27	0.24	0.24	0.26	0.39	1		
(16)	IORG	0.33	0.16	0.32	0.10	0.34	0.30	0.24	0.22	0.24	0.17	0.25	0.20	0.25	0.23	0.33	1	
(17)	IMARK	0.28	0.13	0.25	0.08	0.34	0.23	0.12	0.23	0.32	0.14	0.20	0.18	0.20	0.27	0.23	0.45	1

Table A4.3. Correlation matrix (CIS4; overall sample:7,329 firms)

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1)	RDT_d	1																
(2)	RDT	0.47	1															
(3)	TAT_d	0.63	0.28	1														
(4)	TAT	0.19	0.24	0.46	1													
(5)	PROD	0.69	0.37	0.54	0.17	1												
(6)	PROC	0.55	0.23	0.82	0.42	0.41	1											
(7)	IG	0.26	0.09	0.17	0.00	0.22	0.17	1										
(8)	PATDEP	0.37	0.22	0.25	0.03	0.39	0.19	0.23	1									
(9)	PROT	0.25	0.12	0.21	0.03	0.27	0.18	0.19	0.44	1								
(10)	COOP	0.38	0.29	0.30	0.09	0.36	0.28	0.21	0.26	0.19	1							
(11)	SUPPORT	0.51	0.31	0.54	0.29	0.41	0.53	0.13	0.24	0.18	0.29	1						
(12)	INFO_IN	0.45	0.24	0.46	0.22	0.41	0.42	0.06	0.17	0.13	0.18	0.31	1					
(13)	INFO_EX	0.47	0.23	0.59	0.29	0.41	0.55	0.11	0.18	0.15	0.27	0.42	0.36	1				
(14)	EXP_d	0.30	0.12	0.23	0.02	0.28	0.20	0.24	0.26	0.25	0.14	0.19	0.16	0.17	1			
(15)	LSIZE	0.36	0.11	0.26	-0.03	0.31	0.25	0.56	0.35	0.29	0.24	0.24	0.14	0.20	0.39	1		
(16)	IORG	0.30	0.15	0.29	0.09	0.29	0.30	0.17	0.19	0.23	0.19	0.21	0.18	0.24	0.17	0.24	1	
(17)	IMARK	0.27	0.11	0.24	0.05	0.29	0.24	0.10	0.18	0.32	0.13	0.17	0.15	0.17	0.19	0.15	0.39	1

Chapter V
Concluding remarks and policy implications

This thesis consists of three essays that explore the sources and modes of innovation activity in mature and young firms. In detail, Chapter 2 focuses on the determinants of young companies' R&D activity, while Chapter 3 and 4 study the relationship between different innovative inputs and different innovative outputs by distinguishing among firms of different ages (mature *vs* young). In this concluding chapter I summarise the main findings and derive the policy implications that emerge from them.

The long standing debate regarding the causes of the transatlantic productivity gap has been recently reawakened by some evidence that highlights the important role played by new entrepreneurial entities in increasing the intensity of the innovative effort of entire industries and countries, with particular reference to R&D activity.

The analysis of some important issues related to these aspects, which have recently drawn increasing attention from both policy makers and the scientific community, represents the core of Chapter 2. Indeed, as briefly mentioned before, this chapter looks at possible differences that exist between firms of different ages in terms of the drivers that increase the probability of their engaging in R&D activity, on the one hand, and those that determine the intensity of this activity, on the other hand.

The econometric analyses were performed drawing on a comprehensive panel (Survey on Business Strategy) of Spanish manufacturing firms observed during the period 1990 – 2008, and applying a recently proposed dynamic type-2 tobit estimator, which accounts for individual effects and efficiently handles both the initial condition and sample selection problems.

The results of the estimations clearly suggest that the R&D activity of firms of different ages is driven by different factors. More in detail, if both firms' R&D decisions show a very high degree of persistence over time, young firms in comparison with their mature counterparts show a more erratic path in their innovative process. Moreover, while factors like market concentration and the degree of product diversification are found to be important in fostering R&D activities in the sub-sample of mature firms only, young firms' spending on R&D appears to be more sensitive to demand-pull variables.

While Chapter 2 concentrates its attention on the input side of firms' innovative activity, Chapter 3's main aim is to provide new insights about the determinants of firms' innovative output. In particular, Chapter 3 discusses the sources of product innovation in young and mature firms by looking at different innovative inputs. Along with formal R&D activity, attention is paid to the contribution given by other important external sources of innovation, (external R&D and the acquisition of external technology in its embodied and disembodied components) in determining the innovative output of a firm (both the realization of innovative products and the share of firm's total sales due to sales of new products). This input-output relationship has been tested using a sample of young and mature innovative firms selected from the third wave of the Italian Community Innovation Survey.

Results show that in-house R&D is linked to the propensity to introduce product innovation both in mature firms and young firms; however, innovation intensity in the sub-sample of young firms is mainly dependent on embodied technical change from external sources, while in-house R&D does not play a significant role.

The fourth Chapter of this thesis is closely linked to the third one, and, in some sense, can be seen as an attempt to combine the main elements of the two previous chapters. Indeed, it investigates the determinants of different types of innovative inputs (R&D and technological acquisitions) and their relationship with different innovative outputs (product and process innovation), distinguishing between mature and young firms.

The results of the econometric estimations, obtained by using data from the third and fourth waves of the Italian CIS and applying a 6 equations recursive model, show that different factors have a different impact in determining the innovative choices of the two sub-samples of firms. In particular, young firms appear to be more sensitive than their mature counterparts to the sources of information to innovation with respect to the magnitude of their innovative effort. On the contrary factors like methods of appropriability and support to innovation appear to be more important in enhancing the level of investment in both R&D and technological acquisitions, for the mature firms only. Finally, the two innovative inputs appear to be equally important in determining both innovative outputs for the two sub-samples of firms.

In the light of the discussion presented in the introduction, the findings offered by these different but strictly related works could have an important impact in terms of policy implications. In fact, one of the main causes of the R&D and, consequently, productivity gap between US and Europe is represented by the former's lack of the so called yollies (young leading innovators). Accordingly, shedding some light on the peculiarities of the innovative process of the young companies operating in Europe is vital in order to tackle this negative trend.

The results of the econometric analyses performed in the three previous chapters, and briefly summarized above, give some important insights in this respect. More in detail, they clearly suggest that the age of a firm is a relevant factor in determining its innovative behavior and its innovative performance. To be precise, what emerges is that various firm and market characteristics play distinct roles in boosting different types of innovation activities for young and mature firms. In addition, these two groups of firms seem to show important differences also with reference to the impact of various innovative inputs on their innovative performance.

These general evidence could represent a signal that "erga-omnes" polices aimed at increasing the level of R&D expenditure across all types of industries and firms do not effectively address the real causes of the innovative divide between Europe and the US. As clearly emerges from Chapter 2 and 4, young firms show a different level of sensitivity to some particular R&D drivers with respect to their mature counterparts. Accordingly, specifically designed policies have to be implemented in order to encourage and sustain the birth and growth of entrepreneurial entities that are able to actively contribute to the innovative performance of a country. Moreover, the results show also that young firms are more sensitive to market prospects and demand factors than their mature counterparts with respect to their R&D decision, suggesting possible problems of liquidity constraints for this particular type of firms. The relative inexperience of new born entrepreneurial entities along with their low degree of reputation on the capital market and their lack of sources of collateral and internal funds are all factors that support this conjecture. In this respect, policy measures aimed at tackling possible finance barriers faced by new firms should be put into practice. In particular more attention should be paid to the implementation of finance programmes for the early stages of highly risky innovative projects.

Such policies appear to be even more pivotal in countries such as Italy and Spain where, as it well known, the core of the industrial structure is characterised by the massive presence of traditional and middle-tech sectors. In this respect, only through specific targeted programmes aimed at stimulating the birth and the growth of aspiring young innovators would be possible to renew the industrial structure of these countries and, consequently, to try to recover the gap in terms of R&D intensity and productivity. Along these lines, for example, the econometric results of the third chapter explicitly show that the contribution of Italian young innovative companies in the implementation of beneficial innovative processes (mainly based on investment in R&D) that can lead to the realization of breakthrough innovations is quite negligible. On the contrary, this particular type of firms, in implementing their innovative activities appears to be extremely dependent on external sources of technology. However, although the importance of R&D activity is unquestionable, measures aimed at incentivising other innovative processes complementary to the more formal ones are desirable. In this respect, it is necessary to bear in mind the important role played by the embodied technological change in promoting, particularly in specific sectors, the advance in technology and the corresponding gain in productivity.

The results of the fourth Chapter, in which the determinants of the technological acquisitions along with those of R&D are investigated, could be useful in this respect.

In this case, in fact, emerges that distinct factors have a different impact in boosting different type of innovative activities.

Finally, although the main findings of this doctoral thesis call for the implementation of targeted policies to encourage the birth and growth of young leading innovators, general innovation policies aimed at improving the environment for innovation still remain necessary. Since entrepreneurial innovative entities need to interact and collaborate with other innovators, a specific policy to tackle the lack and weakness of young innovative firms has to be considered complementary and not a substitute for an overall innovation policy. Indeed, as the results of Chapter 4 suggest, policies aimed at encouraging cooperation in innovation activities and at improving the firms' capacities to "absorb" knowledge from internal and external sources of information, could be useful in enhancing the level of investment in R&D and in stimulating the innovative activity of young firms in particular.

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