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Abstract

We use firm-level data from Italian manufacturing firms to assess the relationship between various types of R&D and total factor productivity growth, including collaborative research with other firms and universities. A novel twist to our empirical analysis is that we estimate a treatment effects model, which enables us to treat the decision to conduct R&D as endogenous. We find strong evidence of positive returns to collaborative research with companies, while collaborative research with universities does not appear to enhance productivity. This result implies that firms may conduct R&D with universities when appropriability conditions are weak and the outcomes of such research projects do not yield direct strategic benefits.

Key Words: R&D, Collaborative Research, Total Factor Productivity, Sample Selection Bias
JEL Classification: C21, C80, D24, O30.

I. INTRODUCTION

Technological progress is a central focus of the burgeoning literature on endogenous or "new" growth. Romer (1986, 1990), Grossman and Helpman (1991), and Aghion and Howitt (1998) have developed highly stylized theoretical models in which economic agents intentionally create new products or processes. These models are an extension of the "old" growth theoretical and empirical literature on the relationship between R&D and productivity growth, pioneered by Zvi Griliches and his disciples (Griliches (1998))[1]

The empirical literature on the link between productivity and R&D is vast. There have been numerous studies at the plant, firm, industry, and national levels. As reported in Link and Siegel (2003), much of the firm-level evidence suggests that there are positive returns to R&D. It is important to note, however, that most of these studies do attempt to directly measure the impact of external, collaborative research on firm productivity. Catherine Morrison Paul (2002) has argued that limitations of existing cost or production function models have precluded the consideration of such spillover effects, which might arise from temporal, spatial and sectoral linkages. She asserts that this is unfortunate, since these linkages could have a substantial impact on economic performance.[2] Although it has been widely recognized that spillovers arise when firms are engaged in research activities with external partners (see, e.g., Cassiman and Veugelers, 2002), there is little direct empirical evidence on this phenomenon.

This article uses firm level data from two detailed surveys (conducted in 1995 and 1998) of Italian manufacturing firms to examine the relationship between R&D and productivity growth. More precisely, we use the R&D Capital Stock model developed by Griliches (1979) to assess the contributions of various types of R&D (product, process, internal, external in collaboration with universities, research centers and other firms) to total factor productivity (TFP).

In contrast to most econometric studies of the connection between R&D and productivity, our empirical analysis includes adjustments for selection into R&D, in the sense that firms must first decide whether to engage in R&D at all. This is potentially a major problem, since many companies report zero R&D expenditure. Most empirical studies of the returns to R&D have

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[1] See Link and Siegel (2003) for a review of the old and new growth literatures relating to investment in technology.

been based only on firms that conduct R&D. We conjecture that a failure to take account of the determinants of the decision to engage in innovation might result in overestimation of the returns to R&D (for the representative firm).[3] Given that our data include firms that report zero R&D expenditure, we can estimate a treatment effects model, using sample selection procedures developed by Heckman (1979). This approach has been suggested and implemented in Crepon, Duguet and Mairesse (1998).

The remainder of the article is organized as follows. In the following section, we outline our theoretical model and estimation strategy. Section III describes the data. Empirical results are presented in Section IV. Conclusions and suggestions for additional research are presented in the final section.

II. MODELING THE RELATIONSHIP BETWEEN R&D AND PRODUCTIVITY

We follow the convention in the R&D-capital stock literature, by hypothesizing an augmented Cobb-Douglas production function with constant returns to scale (Lichtenberg and Siegel, 1991):

$$Y = A\left(\prod_i X_i^{\alpha_i}\right)K^{\beta} \qquad (1)$$

where Y is output, A represents disembodied, Hicks-neutral, technological progress evolving at the exogenous rate λ: $A = A_0 e^{\lambda t}$; X_i are conventional factors of production: labor, capital, materials and energy, α_i their elasticities, and K represents the stock of R&D with elasticity β. If we assume constant returns to scale, perfectly competitive factors markets, take logs and differentiate with respect to time, we generate the following expressions for the growth in labor productivity (LPG*)* and Total Factor Productivity (TFPG):

$$\text{LPG} = \lambda + \sum \alpha_i \, \Delta \, x_i + \rho \, \Delta K - (1 - \beta - \sum \alpha_i) \, \Delta l \qquad (2)$$

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[2] A recent exception is Los and Verspagen (2000), who construct both an unweighted and an industry weighted measured of indirect R&D stocks.

[3] See Pakes and Griliches (1980) and Griliches(1990)

$$\text{TFPG} = \lambda + \rho\, (\Delta\ \text{K/Y}) \qquad (3)$$

where lowercases denote labor intensive variables.

Equations (2) and (3) have been used in previous studies to estimate the impact of R&D on productivity, which is usually found to be positive and statistically significant. For instance, Griliches (1980a), Griliches and Mairesse (1984), Odagiri (1983), and Griliches and Mairesse (1983) report estimated returns to R&D ranging between 11% and 31%.[4] More recent studies, such as Lichtenberg and Siegel, 1991; Hall and Mairesse, 1995; Crepon, Duguet and Mairesse 1998; Lööf and Heshmati, 2001) using more detailed firm-level databases and confirm the positive link between innovation and productivity, using a variety of proxies for technological change, such as R&D expenditure, the percentage of sales derived from "innovative" products, and the number of patents. Results relating to the relationship between levels of R&D and productivity are especially robust, while findings based on growth rates of these variables are less robust (Klette and Kortum (2002)). Returns to innovation in these studies are clustered around 30%, although several studies reported insignificant results using data from the 1970's.[5]

Several authors, rather than treating R&D as a homogenous activity, have analyzed the effects on productivity of the different components or types of R&D. For instance, Link (1981b) and Griliches (1986) report that there is a productivity premium associated with basic research, while evidence presented in Griliches and Lichtenberg (1982) and Lichtenberg and Siegel (1991) suggests that while company-funded R&D has a beneficial effect on TFP, federally-funded R&D does not.

Another important distinction in innovative activity at the firm level is between internal and external R&D. External R&D refers to research projects that are conducted in collaboration with other organizations, such as other companies or universities. The literature has emphasized the importance of both types of expenditure, which have been considered as substitutes and complements. The latter viewpoint has recently received a wealth of attention, due to the recognition that it has become increasingly difficult, even for large firms, to rely entirely on their own internal resources to implement successful research projects (Teece (1992), Dodgson (1994), Klette and Kortum (2002)). Indeed, cooperation in R&D enables firms to share costs,

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[4] Results are more heterogenous in studies using small samples (see, e.g., Mansfield (1980), Link (1981a)) and seem to depend on the econometric methodology adopted (cross section, panel data etc). See Mairesse and Sassenou (1991), Nadiri (1993).

reduce risk, and exploit economies of scale and scope. More generally, it could allow firms to exchange complementary assets that often have a tacit nature to them (Freeman (1991), Veugelers (1997)). External R&D expenditure might also be useful in helping the firm enhance its “absorptive capacity”. This refers to the efforts that a firm undertakes to enhance its ability to make use of the research results obtained by rivals through beneficial spillovers (Cohen and Levinthal (1989), Kamien and Zang, 2000).

Maintaining internal research activity could also attract other innovative firms who are seeking partners for their projects (Tether (2002)). However, as the foregoing discussion indicates, the choice of the type of research partner generally depends on firm’s objectives. As noted in Hall, Link, and Scott (2001), partnerships with universities are typically established for long-term basic research projects. These initiatives are often subsidized both at the national level (Siegel, Wessner, Binks, and Lockett (2003), Tidd, Bessant and Pavitt (1997), Tether (2002)). Such subsidization may create perverse effects, as firms are cognizant that cooperation with public partners will reduce their ability to fully appropriate the benefits of the research efforts. Hence, they may opt to enter into the cooperative relationship, as it enhances, at a low cost, their ability to keep abreast of the technological changes that occur in their line of business, but they may also be induced to both exert the minimum effort possible and select projects whose objectives have a low probability to change drastically their industry’s market structure. This may explain the evidence from many existing studies according to which publicly funded R&D did not have any significant impact on productivity.

Finally, as Paul (2002) documents, several authors have found that knowledge spillovers are primarily intra-national, thereby suggesting the importance of opportunities available at the local level. This is particularly important for Italy, where evidence has been found for the existence of “regional systems of innovation” (RSI). These are defined as “the localized network of actors and institutions in the public and private sectors whose activities and interactions generate, import, modify and diffuse new technologies” (Evangelista et al., 2002). In particular, these authors find that the cluster of R&D-based innovative regions is made up of firms from the North West regions and from Lazio, where a large section of the Italian public R&D infrastructure is concentrated. These regions are characterized by a good scientific and technological infrastructure due to the high concentration of universities and public and private

[5] See Lichtenberg and Siegel (1991) and Nadiri (1993).

research institutions. Moreover, there is another innovative cluster including the regions of Emilia-Romagna and Tuscany, where the industrial structure is dominated by small and medium sized firms in the textile and apparel, mechanical, and electronics industries. In this region, the rate of innovation is positively affected by favorable context-specific conditions, such as specialized business services, government-supported local agencies, technology-transfer agencies, private business associations etc. Although in this study we do not directly measure any positive spillover due to research activity conducted within a given region, we indirectly control for regional effects when we analyze the determinants of a firm's decision to conduct R&D.

Our estimation strategy is based on the R&D Capital Stock model from Griliches (1979), as further developed in Griliches (1990). From equation (3) and the hypothesis that R&D has a negligible depreciation rate (as suggested in Griliches and Lichtenberg (1984)), we have:

$$(dK/dt) = \Delta K = R\&D \quad (4)$$

$$TFPG = \lambda + \rho\,(R\&D//Y) \quad (5)$$

where the TFP, expressed in terms of average annual growth, is given by:

$$TFPG = (\Delta Y /Y) - \sum \alpha_i (\Delta X_i /X_i) \quad (6)$$

Equation (5) lends itself to be immediately estimated. However, the presence of a number of firms reporting zero expenditure in R&D creates an econometric problem, i.e., sample selection bias. Indeed, the choice of conducting R&D is endogenous at the firm level. A failure to take account of this might lead to an upward bias in the estimates of the effects of R&D on productivity.

To address this concern, we estimate a treatment effects model that consists of two stages. In the first stage, a Probit selection equation is estimated using the dummy variable "DR," which is equal to 1 if firm *i* reports positive R&D expenditure; 0 otherwise:

$$DR_i = \gamma' W_i + u_i \quad (7)$$

where W is a vector of variables that drive firm i's decision to invest in R&D and u~N(0,1). Thus, equation (5) becomes:

$$TFPG_i = \beta' X_i + \varepsilon_i \quad (8)$$

where $\varepsilon \sim N(\sigma_\varepsilon, 1)$; X_i is a vector of regressors comprising different measures of R&S plus a number of dummy variables that captures firm's specific characteristics, namely dimension and geographical location. In the subsequent analysis, ρ denotes the correlation between u and ε. When u and ε are correlated, in the second stage the following model is estimated:

$$TFPG_i = \beta' X_i + \beta_\lambda \lambda_i (\gamma W_i) \quad (9)$$

where $\beta_\lambda = \rho\sigma_\varepsilon$, and $\lambda_i = \phi(\hat{\gamma} W_i) / \Phi(\hat{\gamma} W_i)$ is the *inverse Mill's ratio* that is added to the structural equation. Therefore, this procedure, which was adapted by Barnow, Cain and Goldberger (1981) to the treatment effect case, deals with the sample selection problem as one of an omitted variable. It is therefore analogous to that proposed by Heckman (1979), although the latter, in the second stage, only considers the sub-sample of cases that report a positive value of the dependent, rather than of an independent, variable. Therefore, in the treatment effect model, all cases are included in the second stage. The estimation procedure can be summarized as follows (Verbeek, 2000):

$$TFPG_i = [\beta' X_i | DR_i = 1] * Pr[DR_i = 1 | W_i] + \}[\beta' X_i | DR_i = 0] * Pr[DR_i = 0 | W_i] \quad (10)$$

Table 1 presents a list of the variables used in the empirical analysis. The econometric procedure presented above constitutes a reduced version of the model proposed by Crepon, Duguet and Mairesse (1998) and Lööf and Heshmati (2001), who used a multiple equations model developed by Pakes and Griliches (1980). In these papers, a measure of R&D output (e.g. number of innovative products or patents) is used instead of R&D expenditure. However, it must be stressed that not all research activity results in a patent, partly because the firms may want to maintain their know-how secret and partly because certain innovations are not patentable, although they may significantly contribute to productivity enhancements.[6]

[6] See Siegel, Waldman, and Link (2003) for further discussion of this issue.

III. DATA

Our data are derived from surveys conducted by Mediocredito Centrale (www.mcc.it), an Italian investment bank, in 1995 and 1998, respectively. Both surveys requested information on the firms' innovative activity for the three years prior to their implementation, that is, 1992-94 and 1995-97. The *Mediocredito Centrale* surveys consist of three types of data: 1) balance sheet data 2) conventional input and output data, such as sales, employment, capital investment, and R&D expenditure, and 3) qualitative and scaled response data regarding the firm's competitive environment, group membership and position within the group, and industry characteristics. Firms with fewer than 500 employees were selected using a stratification procedure based on size, industry and geographical location. All firms with more than 500 employees were included in the survey. That is, we have the entire universe of large firms and our final sample represents a very large percentage of overall economic activity in the manufacturing sector.

For each firm, we have more than 500 variables, with balance sheet data for up to nine years (1989-1997) for the 1998 survey and up to six years (1989-1994) for the 1995 wave. Unfortunately, R&D expenditures were available only for three years (1995-97 and 1992-1994) in each survey. Furthermore, only a limited number of firms were present in both surveys, which resulted in our decision to conduct our econometric analysis on the two samples separately.[7]

To compute average growth in TFP, we used a long difference approach where we consider the change between the years 1997 and 1995 for the sample from the 1998 survey, and the years 1994-1992 for the sample from the 1995 survey. Firms with a TFP growth rate measure outside the interval ±30% were considered outliers and eliminated from the sample. To reduce potential simultaneity problems, we used R&D expenditures only from the first year of the period under analysis, that is, 1995 and 1992. Overall, after accounting for missing values, we obtained a sample size of 2268 firms for the period 1992-94 and 2215 for the period 1995-1997.

With respect to the calculation of *TFP* from (6), Gullikson (1995) suggests that when firm level data are used, *Y* is better represented by sales than by such other measures as value

[7] Data from the first survey were used by Piga (2002) to study the strategic use of debt in vertical relationships, while the decision to conduct cooperative R&D and its antecedent decision to engage in R&D are jointly studied in Piga and Vivarelli (2003) using the 1998 survey.

added.[8] Capital, labor and materials and energy are the three factor inputs. The growth of capital was calculated as the growth rate of tangible assets net of depreciation; the items considered for the evaluation of the costs for material and energy were the costs for materials, for services and other costs; for labor, we calculated the variation in the number of non-R&D employees, weighted by the number of part-time workers, to avoid the double counting problem.

Indeed, as suggested in Griliches and Mairesse (1984), in evaluating TFP, factor inputs should be considered net of any R&D cost, because failing to do so leads to underestimation of the R&D returns. Unfortunately, we do not have this information for the amount of tangible assets, materials and energy that were used specifically for R&D purposes. Thus, the coefficient ρ in (5) will be considered as a return in excess to the average remuneration of the traditional production inputs. Furthermore, in the evaluation of *TFP* in (6), the α_i coefficients represent each factor's elasticity of production. Note that under the assumption of perfectly competitive markets for factor inputs, these elasticities are equal to the respective cost shares. To work these out, for each firm in the two samples, the shares of labor costs and materials and energy costs over total costs were calculated for the initial and the final year, and then their average value was considered. Following Lichtenberg and Siegel (1991), the cost share of capital was calculated as a residual. All variables expressing monetary values from both the 1998 and the 1995 survey were deflated using, respectively, the 1995 and the 1990 indexes of inputs prices. The deflators for nine different industries were used: these were also disaggregated by geographical location to take into account differences between the input prices in the North West, North East, the Centre and the South of Italy.

Definitions of all the regressors used in our empirical analysis are reported in Table 1. Table 2 provides a summary description of the composition of the statistical samples derived from the two waves of the survey. This table reveals that our sample consists of many firms in sectors K (Industrial Machinery), L (Electric and Electronic equipment; Instruments), J (metals and metallic products) and B (textiles and apparel). Taken together, these four industries account for 40.2% of all the firms in the 1992-94 sample, and 36.8% in the 1998 sample. More than 40%

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[8] Sales was also used as a measure of output in Los and Verspagen (2000).

of firms in both samples are based in the North West of Italy.[9] However, the 1995 survey includes more than 50% of firms in the 51-250 class size, while the second survey includes a majority of small firms with 50 or less employees.

Descriptive statistics for the variables used in both stages of the estimation are reported, for the two samples, in Table 2 and 3 respectively. Table 3 shows that 1008 firms out of 2268 (44.4%) have reported strictly positive R&D expenditures, amounting to 1.84% of total sales. Table 4 indicates that in the 1998 survey the number of firms engaged in R&D fell to 689 (31.1% of total), each investing on average 1.41% of their 1995 total sales. In the first period, the most R&D intensive sector is that of electrical and optical machines (2.49%), immediately followed by the mechanical machinery (2.2%) and the transportation industry (2.08%). In the second period the most R&D intensive sector is the chemical one (2.13%), followed by the previously mentioned sectors. Internal R&D expenditure is predominant in the mechanical machinery industry (over 70%) while the chemical and plastic product sector reports the highest level of external R&D expenditures. The less R&D intensive sectors are the traditional sectors of food and tobacco, shoes and leather, stone, clay and glass, and petroleum with less than 1.0% of total sales invested in R&D.

In the 1998 survey, we can disaggregate external R&D expenditure into three categories: expenditure on research with universities, other research centers, and other companies. Collaboration with universities is particularly intense in the electrical machines and optical sectors, and practically absent in the wood products, in the petroleum and in the stone, clay and glass industries. In the chemical sector collaboration is mostly made together with research centers. Cooperation with other firms is important in the chemical, the transportation and the industrial machinery sectors.

Product R&D generally exceeds its process counterpart by a factor of 1.7, although it has to be noticed that the food and tobacco and the petroleum industries invest more in process R&D. In both samples, the firms in the North-East and in the Centre are the most R&D intensive, while those in the South lag behind. However, the latter tend to seek the collaboration of universities, although the firms in the Centre of Italy spend more than the others in external

[9] The geographical compositions in the two samples is similar to the one reported in Evangelista et al. (2002) who use the Italian data collected for the European project known as the "Community Innovation Survey" comprising 22787 firms.

collaborations, especially with other firms. No significant difference can be noticed with regards to the relationship between firm's size and R&D intensity, although small firms tend to invest more in external R&D, especially with other firms.

We now turn to our descriptive statistics on productivity, which reveal distinct differences in performance. In 1992-94, the average annual growth in TFP was 2.2%, while the corresponding figure for 1995-97 was -0.94%. Among the industries that record results in contrast with the periods' average trend, the stone, clay and glass sectors registered a slow down in the first period (-3.1%) while the chemical (+1.6%), the petroleum (+0.5%) and shoes and leather (+0.3%) sectors are the only ones to record an increase in productivity in the second period. In both periods, the firms located in the North West of the country are associated with the best performance in terms of TFP, while small firms with less than 50 employees under-performed relative to their medium and large counterparts.

IV. RESULTS

Table 5 reports the estimates from the selection regressions for both samples. We use the same variables in the selection equation (eq. (7)) as Piga and Vivarelli (2003). The estimates are generally consistent in both regressions and carry the expected signs. The negative and highly significant constants indicate that small firms located in the South of Italy operating in the Food and Drinks industry are less likely to report positive R&D expenditure. Export intensity is positively associated with the probability of engaging in R&D. The findings also suggest that formal innovative activity is more likely to occur in large, multiproduct firms and those that have a greater proportion of intangible assets and employees with a degree. The opposite seems to occur in those firms that concentrate their sales on the three main clients. Finally, the evidence suggests a tendency, for those firms belonging to a group, to concentrate their research at the holding firm level.

Parameter estimates of the TFP treatment effect model for the 92-94 sample are reported in Table 6. As expected, there is a positive association between R&D and productivity growth. Note that our estimate of a 29% "return" to R&D is fairly consistent with previous studies. The results presented in the second column of Table 6 suggest that internal and external R&D activities both have a positive and significant impact on productivity. However, it appears as though the returns to external R&D are higher than those associated with internal R&D. This difference is statistically significant. The third set of findings implies that process R&D yields higher returns than product R&D, although this difference is not statistically significant.

Similar patterns emerge when we estimate the TFP treatment effects model using data from the later period (95-97). These findings are presented in Table 7. Once again, we find that the returns to external R&D greatly exceed those resulting from investment in internal R&D. More importantly, the estimates in the third column of Table 7 reveal that the impact of external R&D depends on the nature of the research partner or collaborator. Indeed, the results suggest that engaging in external research projects with other firms significantly enhances productivity, while collaboration with universities does not. Between these two extremes lies the impact of R&D expenditures within private or public research centers, whose coefficient is positive and significant at the 10% level.

These results are consistent with the view that firms allocate their external R&D in a manner that maximizes the private return on investment. That is, strategic research projects are shared with other private firms, since this reduces the risk that the research results will be appropriated by competitors. More basic research that is unlikely to yield marketable products or more efficient processes in the near future, but that may be nonetheless useful for maintaining a firm's absorptive capacity, is conducted with universities. The incentives for research centers, even public institutions, to disseminate the results of their research activity is weaker than in universities, as they can exploit them for commercial purposes. Thus, firms are more willing to collaborate and share resources with research centers, as spillovers may be more easily internalized. From a more general viewpoint, our findings support the notion that spillovers arising from a firm's spatial and sectoral linkages may enhance a firm's productivity growth (Paul, 2002).

As a final empirical point, we stress that the unobserved characteristics included in ε_i in equation (9) may be correlated with the firm's decision to invest in R&D. This correlation could introduce sample selection bias in conventional econometric estimation of the reduced form R&D-productivity equation. This seems to be the case in our two samples. Indeed, we could reject the null hypothesis of no selectivity bias in all our models, as the coefficients on LAMBDA are significant in both periods. The negative sign indicates the existence of unobservable characteristics that positively (negatively) influences a firm's decision to engage in R&D, but that negatively (positively) affects its productivity. Thus, the evidence from both surveys lends some support to our methodological choice to analyze the relationship between R&D and TFP using a treatment effects model.

V. CONCLUSIONS AND SUGGESTIONS FOR ADDITIONAL RESEARCH

We have investigated the link between a firm's productivity growth and its innovative activity, as identified by various measures of R&D expenditures (internal, external in partnership with other firms, universities and/or research centers, process and product). Our findings yield several preliminary conclusions. First, sample selection issues are found to be important when R&D is used to explain changes in productivity. Because many firms do not conduct R&D, it is necessary to explain the process by which firms choose to invest funds in formal research. Thus, a two-stage treatment effect model was used in our empirical analysis. In the first stage, we estimated a Probit regression of the selection process. In the second stage, we estimate reduced form equations from the R&D capital stock model, in order to assess the relationship between TFP and R&D. A failure to take account of selection effects may result in biased estimates of the returns to R&D. Note that we still find that R&D has a positive and significant impact on productivity, even after controlling for sample selection bias.

Another key preliminary conclusion is that external R&D generates a significantly higher return than internal R&D. However, these positive returns appear to be driven primarily by external research projects with other companies and research centers. On the other hand, investment in external collaborative research with universities does not appear to generate a direct positive return to the firm.

There are several possible interpretations of this result. One interpretation is that firms use universities as research partners when the research outcomes do not have important strategic consequences. For instance, firms may delegate to universities the implementation of quality controls that guarantee their products' compliance with minimum regulatory safety standards. However, the usual intellectual property rights and appropriability difficulties seem to indicate that for the firms in our samples, external R&D with universities is a particularly unattractive strategy to acquire a strategic advantage (Love and Roper, 2002).

It is important to bear in mind that this finding may be due to the limited time span over which we have analyzed changes in TFP. That is, firms are likely to engage in applied research with other firms and this research may generate benefits within a few years. If firms are mostly engaged in basic research projects with universities (Hall, Link, and Scott (2003)), marketable outcomes resulting from this research may fail to materialize for many years. However, research with universities has been found to increase a firm's internal "absorptive capacity" (Cockburn and Henderson (1998) and (Hall, Link, and Scott (2003)). Thus, it may contribute to a firm's long-run viability because it enables a firm to keep abreast of scientific developments, thereby enhancing its possibility to take advantage of the technological opportunities available at the geographical and/or sectoral level.

In future empirical research, we hope to estimate a longer time series, in order to discriminate between these alternative interpretations of a zero (private) return to collaborative research with universities.

Table 1
Variables Names and Description

TFPK__	TFP Average yearly Growth rate (**24**: 1992 – 94; **57**: 1995 – 97)
R&DS__	R&D expenditure divided by Sales (**92**: 1992; **95**: 1995)
R&DINS__	R&D expenditure in internal labs and structures over Sales (**92**: 1992; **95**: 1995)
R&DEXS__	R&D expenditure in external labs and structures over Sales (**92**: 1992; **95**: 1995)
R&DOFS95	R&D expenditure in external labs and structures owned by other firms over Sales (1995 only)
R&DUNS95	R&D expenditure in external labs and structures owned by Universities over Sales (1995 only)
R&DECS95	R&D expenditure in external labs and structures owned by research centers over Sales (1995 only)
R&DDS__	R&D expenditure aimed at the improvement and/or creation of products over Sales (**92**: 1992; **95**: 1995)
R&DCS__	R&D expenditure aimed at the improvement and/or creation of processes over Sales (**92**: 1992; **95**: 1995)
RESERVE	Ratio of accumulated Retained Earnings over Total Assets (1992; 1995)
HEADGR	Dummy=1 if a firm is the holding or controls other firms within a group organization (1992; 1995)
LNEMP	Size measured as the natural log of number of employees (1992; 1995)
INTASS	Ratio of 1994 Intangible Assets over Total Assets
DINF	Dummy =1 if firm invested in 1995-1997 to improve its Information Technology (IT) equipment.
COMPABR	Index of extent of competition from foreign firms measured as the square root of the sum of the three dummy variables specifying whether the main competitors are localized, respectively, in the European Union, in other industrialized countries and in developing countries.
MAIN3CL	% of total sales to the three main clients (1992; 1995)
PRODDIVE	Index of Product diversification= $1/(\Sigma s_i^2)$, s_i = Shares of sales from product group *i* (1995)
HUMLAU	Percentage of employees with degree or post-graduate qualifications (1992; 1995)
EXPFATT	Percentage of export sales over Total Sales (1992; 1995)
NWEST	Geographical dummy =1 if firm located in the North West of Italy
NEAST	Geographical dummy =1 if firm located in the North East of Italy
CENTRE	Geographical dummy =1 if firm located in the Center of Italy
SOUTH	Geographical dummy =1 if firm located in the South of Italy
EMPL_	3 Dummy variables for size classes (**1**: $11 \leq x \leq 50$; **2**: $51 \leq x \leq 250$; **3**: $251 \leq x$

Table 2
Descriptive Statistics: Composition of Samples by Industry, Location, Size, and R&D Activity

	1992-94		1995-97	
	N	% of sample	N	% of sample
	Region		**Region**	
NEAST	735	32.4%	640	28.9%
NWEST	1039	45.8%	912	41.1%
CENTRE	345	15.2%	356	16.1%
SOUTH	149	6.6%	309	13.9%
	Industry		**Industry**	
Food, Tobacco	99	4.4%	239	10.8%
Textiles; Apparel	288	12.7%	317	14.3%
Shoes, Leather	111	4.9%	82	3.7%
Wood and Wood Products	47	2.1%	62	2.8%
Paper; Printing	238	10.5%	145	6.5%
Petroleum, Coal	15	0.7%	9	0.4%
Chemicals	221	9.7%	114	5.1%
Rubber, Plastics	130	5.7%	145	6.5%
Stone, Clay, Glass	59	2.6%	141	6.4%
Metals and Metallic Products	250	11.0%	276	12.4%
Industrial Machinery	284	12.5%	366	16.5%
Electric and Electronic equipment; Instruments	340	15.0%	135	6.1%
Transportation	158	7.0%	84	3.8%
Misc.: Furniture, Jewelry, Musical Instruments, Toys	28	1.2%	102	4.6%
	Size		**Size**	
DIP50	676	29.8%	1117	50.4%
DIP250	1237	54.5%	809	36.5%
DIP500	355	15.7%	291	13.1%
	R&D>0		**R&D>0**	
FILRES=1	1008	44.4%	689	31.1%

Variables' definition is in Table 1

Table 3
Descriptive Statistics of the 1992 – 1994 sample by R&D involvement

Full Sample: N=2268					R&D Sample: N=1008				
	Mean	Std.Dev.	Min	Max		Mean	Std. Dev.	Min	Max
RESERVE	0.152	0.141	-0.228	0.880	RESERVE	0.141	0.131	-0.228	0.742
HEADGR	0.164	0.371	0	1	HEADGR	0.236	0.425	0	1
LNEMP	4.516	1.065	2.398	9.763	LNEMP	4.857	1.069	2.512	9.763
INTASS	0.021	0.044	-0.493	0.452	INTASS	0.024	0.049	-0.205	0.429
HUMLAU	0.033	0.058	0	0.652	HUMLAU	0.046	0.069	0	0.585
EXPFATT	0.310	0.298	0	1	EXPFATT	0.386	0.295	0	1
R&DS92	0.008	0.019	0	0.177	R&DS92	0.018	0.024	0.000	0.177
R&DINS92	0.007	0.017	0	0.170	R&DINS92	0.016	0.022	0	0.170
R&DEXS92	0.001	0.005	0	0.071	R&DEXS92	0.003	0.007	0	0.071
R&DDS92	0.006	0.014	0	0.132	R&DDS92	0.012	0.020	0	0.132
R&DCS92	0.003	0.007	0	0.097	R&DCS92	0.006	0.010	0	0.097
TFPK24	0.022	0.055	-0.279	0.258	TFPK24	0.025	0.053	-0.279	0.253

Variable Definitions are presented in Table 1

Table 4
Descriptive Statistics of the 1995 – 1997 sample by R&D involvement

Entire Sample: N=2217					R&D Sample: N=689				
	Mean	Std.Dev .	Min	Max		Mean	Std. Dev.	Min	Max
MAIN3CL	0.340	0.248	0	1	MAIN3CL	0.317	0.243	0	1
PRODDIVE	0.012	0.005	0.01	0.123	PRODDIVE	0.013	0.007	0.010	0.123
HEADGR	0.143	0.350	0	1	HEADGR	0.241	0.428	0	1
LNEMP	4.124	1.096	1.992	8.944	LNEMP	4.694	1.216	2.457	8.944
INTASS	0.017	0.035	0	0.473	INTASS	0.020	0.039	0	0.411
HUMLAU	0.047	0.071	0	0.845	HUMLAU	0.060	0.079	0	0.845
EXPFATT	0.305	0.303	0	1	EXPFATT	0.400	0.299	0	1
R&DS95	0.004	0.013	0	0.169	R&DS95	0.014	0.020	0.000	0.169
R&DINS95	0.003	0.010	0	0.143	R&DINS95	0.011	0.016	0	0.143
R&DEXS95	0.001	0.005	0	0.151	R&DEXS95	0.003	0.009	0	0.151
R&DECS95	0.000	0.004	0	0.144	R&DECS95	0.001	0.007	0	0.144
R&DOFS95	0.001	0.003	0	0.082	R&DOFS95	0.002	0.006	0	0.082
R&DUNS95	0.000	0.001	0	0.031	R&DUNS95	0.000	0.002	0	0.031
R&DDS95	0.003	0.011	0	0.169	R&DDS95	0.009	0.018	0	0.169
R&DCS95	0.002	0.005	0	0.078	R&DCS95	0.005	0.008	0	0.078
TFPK57	-0.009	0.047	-0.297	0.265	TFPK57	-0.008	0.048	-0.252	0.265

Variable definitions are presented in Table 1

Table 5

Probit Estimates of the Selection equation: "*Does the firm have a positive R&D expenditure?*"

	1992-94			1995-97		
	Coeff.	sig	t-ratio	Coeff.	sig	t-ratio
CONST	-2.203	***	-11.819	-3.052	***	-16.569
INTASS	1.350	*	1.932	1.419	*	1.710
HEADGR	0.206	**	2.495	0.143		1.589
HUMLAU	2.971	***	5.129	1.877	***	4.356
EXPFATT	0.589	***	5.809	0.467	***	4.262
LNEMP	0.276	***	8.877	0.320	***	10.066
RESERVE	-0.481	**	-2.300			
MAIN3CL				-0.375	***	-2.869
PRODDIVE				11.517	**	2.142
DINF				0.474	***	6.225
NWEST	0.485	***	3.745	0.277	**	2.551
NEAST	0.410	***	3.241	0.299	***	2.891
CENTRE	0.347	**	2.479	0.357	***	2.960
Dep. variable	DR			DR		
N	2268			2217		
Chi Sq	465.21	***		484.10	***	
Pseudo R^2	0.4904			0.4898		

***, **, * Significant at the 1%, 5% and 10% level respectively. Includes 9 industrial dummy variables. Variables' definition is in Table 1

Table 6
TFP Regressions 1992 – 94
Dependent Variable: Average Annual TFP Growth

	Coeff.	sig	t-ratio	Coeff.	sig	t-ratio	Coeff.	sig	t-ratio
CONST	0.012	***	6.223	0.012	***	6.221	0.012	***	6.197
R&DS92	0.290	***	4.302						
R&DINS92				0.239	***	3.073			
R&DEXS92				0.599	**	2.453			
R&DDS92							0.260	***	2.949
R&DCS92							0.388	**	2.285
LAMBDA	-0.003	**	-2.061	-0.003	**	-2.079	-0.003	**	-2.107
N	2268			2268			2268		
Adj. R^2	0.058			0.058			0.058		
F	14.88	***		13.69	***		13.59	***	

***, **, * Significant at the 1%, 5% and 10% level respectively. Includes 9 industrial dummy variables. Variable definitions are presented in Table 1

Table 7
TFP Regressions 1995 – 97
Dependent Variable: Average Annual TFP Growth

	Coeff. sig	t-ratio	Coeff. sig	t-ratio	Coeff. sig	t-ratio	Coeff. sig	t-ratio
CONST	-0.005***	-3.142	-0.005***	-3.123	-0.005***	-3.121	-0.005***	-3.147
R&DS95	0.364***	4.330						
R&DINS95			0.282***	2.668	0.272**	2.496		
R&DEXS95			0.577***	3.098				
R&DECS95					0.475*	1.804		
R&DOFS95					0.709**	2.381		
R&DUNS95					0.651	0.624		
R&DDS95							0.337***	3.494
R&DCS95							0.446**	2.170
LAMBDA	-0.003*	-1.901	-0.003*	-1.826	-0.003*	-1.843	-0.003*	-1.908
N	2217		2217		2217		2217	
R^2 adj	0.037		0.037		0.036		0.036	
F	8.67***		8.09***		6.95***		7.91***	

***, **, * Significant at the 1%, 5% and 10% level respectively. Includes 9 industrial dummy variables. Variable definitions are presented in Table 1

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