Liberalisation, industry turmoil and the balance of R&D activities

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ABSTRACT

The paper addresses the following research question: is market turmoil a determinant of R&D expenditure? Specifically, we will try to understand whether market turmoil affects the balance between basic and applied industrial research activities, when the turbulence is the consequence of a liberalisation process.
We present an empirical model which is set to demonstrate that industry market turmoil is likely to provide firms with short term incentives, shifting the allocation of resources towards applied and development activities. We discuss the implications of such model against the background of the recent developments in European telecom markets, arguing that the dynamics outlined in the model are likely to jeopardise the nations' ability to foster and sustain an appropriate rate of innovative activity.

1 INTRODUCTION

In this paper we are keen on demonstrating that industry turmoil following an exogenous shock is bound to modify the profile of firms' R&D efforts, shifting resources towards short term research objectives. Although our interest is in any generic exogenous shock able to reshuffle an industry's configuration, and the hypotheses are rather general, we have taken inspiration by the clearest example of exogenous shock, the process of market liberalisation. Furthermore, we have chosen to make our story specific by electing the telecom sector as an empirical test-field for our model.

Over the last decade, European telecom markets have eventually started their processes of liberalisation. The old monopolies of PTOs have systematically been replaced by liberalised markets, in which domestic and foreign investors are striving hard to establish and consolidate their market positions. Italy has long ago liberalised the telecom manufacturing sector and has very recently introduced competition in the service provision one. In Italy, just like in other countries that are already a long way down the road of liberalisation, the debate about the effects of competition has now reached its peak. The vast majority of the arguments advocated tends to support the idea that the net effect of the institutional change will be positive, both socially and for the incumbent firm. Nevertheless, there also seems to be a widespread awareness about the existence of potential sources of market failures, as witnessed by the ever-increasing regulatory activity performed by national authorities. Among the controversial issues, the debate about the actual suitability of market incentives to generate and sustain an appropriate rate of technical progress within the country has until now occupied a relatively marginal position. The crucial question is how, and how much, firms' R&D expenditure profile will be affected by institutional transition generating industry turmoil, both in terms of total amount and in terms of composition.

Although the focus of the paper is strictly on the latter issue, it has to be mentioned that the former has long been a crucial matter of debate both in the literature and on empirical grounds. Under a few general assumptions, the theoretical literature on market structure and innovation shows that, aside from the effects of technological spillovers, the amount of R&D expenditures in a monopolistic industry is smaller than in an oligopolistic one, although smaller in single oligopolistic firms (see for instance Kamien *et al*., 1992 and prominently, Sutton, 1999). An excellent review of empirical findings on this matter is to be found in Cohen (1994). However, this literature is silent on the *composition* of R&D; as a consequence, it does not address the issue of longer-term, basic R&D activities, and, thus, it does not need to discuss the effects of industrial turmoil. In the reminder of this section we will review briefly the evidence available about R&D intensity whilst we will try to get a deeper insight on the issue of R&D composition.

Table 1 reviews R&D expenses of leading telecom operators. It is well evident that the research efforts have smoothly increased over the last few years in absolute terms, although they still represent a modest fraction of net sales. With the exceptions of NTT of Japan and Telia of Sweden, telecom operators have spent in 1996 roughly 1% of their revenues on R&D activities. The trend of R&D intensity in the world's largest PTO is shown in Table 2. Both BT and NTT have maintained an almost unchanged level of R&D

intensity over the last ten years, following liberalisation. Conversely, the manufacturing sector evidences much higher R&D / Revenues ratios (see Table 3). Individual firms' data, do not show any clear trend over the last four years, our sample being almost equally split into moderately increasing and decreasing trends. It is interesting to notice, though, that R&D intensity varies considerably among the firms, ranging from a 15% at Ericsson to a 5% at CISCO and Matsushita. This observation is somehow confirmed in Table 4, which shows R&D expenses in a two-digit level classification of industries. Unfortunately, due to disclosure clauses, figures for the industry code 4.8 (communications) are not publicly available. Nevertheless, it can be noticed that the electrical equipment sector (36) has considerably decreased its R&D intensity at the beginning of the nineties, consolidating a 6% ratio that has been maintained all through the decade.

The evidence for Italy, the specific country in which our interest is, is evidenced in Table 5. R&D intensity in the manufacturing sector has shown a decreasing trend, starting from a consolidated 10% at the beginning of the nineties, whilst the post and communication sector has sensibly increased the amount of resources allocated to research, growing from 0.37 % in 1993 to 3.31% in 1997. This latter figure[1] would seem to indicate that expectations on liberalisation have exerted a positive effect on the incumbent's incentive to allocate resources to research (in Italy the process started formally in early 1998).

A comprehensive review of different R&D strategies at AT&T, NTT and Bell after liberalisation is provided by Fransman (1994a, 1994b), Grupp and Schnoring (1992), Harris (1990) and Noll (1987). In different countries, experience has shown that there is no conclusive evidence that the overall R&D expenditure has either decreased or increased after liberalisation. Other countries of continental Europe could be used to support either hypothesis, but this would take us far beyond the scope of this discussion.

Our main objective here is to discuss the effect of market turbulence on the profile of R&D expenses, as defined by the ratio between resources allocated to either basic or applied resources. Academic literature has almost entirely neglected this issue, whilst the corpus of empirical evidences is fairly suggestive.

A recent report from the National Institute for Science and Technology (NIST, 1999) stresses that the IT sector invest in R&D activities an amount that represents between 21 and 35 percent of all private R&D investment in the US. Nevertheless, several of the largest IT industrial R&D laboratories have undergone severe downsizing and have focused remaining research efforts on supporting shorter term development goals. Estimates for the IT industry indicate that 6 percent to 9 percent of R&D expenditure go toward long term basic research. The report is pretty clear about the determinants of this trend: support from long term research is shrinking as profit margins erode due to intense global competition in products with shorter lifecycles. R&D is now viewed as just another expense item that competes against sales, marketing and general management expenses.

[1] The figure should be regarded at with some caution, being a preliminary estimate.

These comments are reinforced by the vision expressed by Gregory Tassey[2] in a NIST briefing note (NIST 1999). Mr. Tassey observes that the scope of R&D market failures has broadened in several key respects, resulting in significant under-investment relative to the optimum level and composition of R&D needed for economic growth. The report stresses that the composition of US private sector R&D is shifting toward shorter term objectives, at the expenses of next generation research. U.S. industry is attempting to become more efficient in the conduct of applied R&D, the effort manifesting itself in the 1990s in the form of shorter R&D cycles times, cutting the average time by 45 percent (18 months to 10 months in a five year period). Such strategy shifts are causing compositional market failures in R&D investment, suppressing private sector incentives to invest in next generation research. When global technology based competition was less robust, the average technology life cycle was sufficiently long to allow U.S. industry to apply lower discount rates to projected returns from R&D investments and thereby undertake more next generation technology research. It is well evident that the evolving competitive scenario will radically change the situation, imposing very high discount factors to long term research projects.

A number of sharp comments were reported, pointing at the sharp redirection in US science. Bellcore Labs were reported to have stopped most long term research in physics to focus on the immediate needs of the customers, and the same for IMB, AT&T, Exxon and Dupont. (Business Week, 1994). Worries were legitimated by the comparison with the Japanese industry that in 1994 the Council on Competitiveness estimated to spend nearly 50% on long term projects versus less than 22% for the US industry. Most US firms manifested their ambition to get their blue sky research down to earth (Business Week, 1995), motivating Bellcore's Heilmeier[3] to express his concern in these terms: "It is now legitimate to ask who will do long term, more basic research in the future" (Business Week, 1994).

Almost every commentator seemed to attribute the insurgence of this trend to increasing competition on global markets. This was utterly true in R&D intensive sectors as the telecom one. Though, US telecom industry seemed to perceive the threats intrinsic in a massive downsizing of long term R&D and many signs of awareness and determination to contrast the phenomenon can be traced in the words of many commentators and managers. In particular, the problem of co-ordinating basic and applied research efforts emerged as a top priority in research managers' agenda. The Industrial Research Institute has been surveying its membership annually since 1993 to identify the biggest problems for technology leaders (Table 7). The item "Balancing long-term/short-term R&D objectives/focus" was identified as the second most important problem every year of the survey except 1996 (where it ranked first) and 1993 (third). Lucent's Bell labs in 1998 could count on a $3.7 billion budget for R&D thanks to the decision to allocate a fixed 11% of revenues to research. Lucent also established an internal venture capital operation to fund researcher's ideas that do not fit into existing business (Business Week, 1999). The New Ventures Group at Lucent, just like the Xerox Technology Venture at Xerox, are there to assure that any scientist coming up with a good idea has a legitimate chance to get it financed (The Economist, 1999). The problem is also gaining increasing

[2] Director of the Office of Strategic Planning and Economic Analysis, NIST
[3] Formerly Bellcore President

consideration in the academic literature, as witnessed by the recent contribution from Cockburn et al. (1999).

Telecommunications carriers have experienced similar problems and in accommodating long and short term research objectives. A comprehensive review is provided in (Fransman, 1994). BT and NTT allocated, in 1994, about 10% of their R&D budget to projects with a commercial time horizon of 10-20 years. There seemed to be little, if any, basic research undertaken in BT's laboratories, at least insofar as this refers to research undertaken without any practical or commercial objective in mind. Even in case of long term research, BT put in practice a tight "customer-supplier" principle, establishing a "Program Office" structure in order to define a portfolio of research projects. The portfolio is managed to comply with the broad strategic directives agreed by the Technology Research Board, and the project scope is strictly monitored by an advisory committee of experts selected from business week across the group. About the same is to be said about NTT; Basic Research Laboratories consume about 6% of NTT total R&D budget and it has been protected as a priority area from budget cuts. Nevertheless, the Basic Research Laboratory is characterised as undertaking long term oriented basic research. It is here interesting to notice that the different attitude of BT and NTT to basic research is probably the result of different obligations to do research in the nation's interest, which are very strong for NTT but weaker for BT. We interpret this point as a robust evidence of the possible dynamic inefficiencies arising when competition weakens single firms' obligations to provide a public good (scientific knowledge) to the national system of innovation as a whole.

This kind of attitude is certainly an important indicator of big firms' attention to the problem of financing basic research activities. Though, the underlying structure of incentives clearly evidences the attempt of substituting directed basic research activities to pure blue sky research. Here, probably, the coherence between figures in Table 6 and managers' fears can be reconstructed: it is the nature of basic research that changes, although the total amount of resources allocated does not vary much. In the words of Nobel laureate Arno Penzias[4], "…we really had to understand the difference between long term research valuable to the company and academic research, and we needed to prune the academic part…". Although this is not necessarily a source of market failure, it is hardly plausible that drawing the line between valuable and academic research will be terribly easy. We argue that contingencies can make the perceived border between valuable and non-valuable research drift well towards applied short-term projects. It is in the telecom sector that we study such contingencies.

Data on the US telecom industry basic research are rather scarce. Table 8 shows the aggregate expenditure for total and basic research activities in the communications sector in the Unites States. Unfortunately, most of the data have been withheld in order to avoid disclosing operations of individual companies. The only complete decade that we can trace back is the aggregate electrical equipment classification (36), which confirms the trend depicted above, evidenced by a sharp reduction in basic research share, beginning in the early nineties and a robust upward trend since 1995. The only two definitive figures available for the specific communication equipment segment show a downward

[4] Formerly Bell Labs Research Chief

trend in basic research between 1995 and 1996, followed by a sharp increase in 1997 (preliminary figure). Data on the communications sector (48) are not publicly available. Given the scarcity of information, it is very difficult to assess a precise causal relationships between changes in market structure and R&D profiles.

Other interesting evidences are displayed in Table 9 and in Table 10, showing the number of firms performing basic research activities in selected sectors. Table 9, illustrated in Figure 1 and Figure 2, evidences a general downward trend in the total number of firms carrying on any research, and a stable number of firms conducting basic research. As a consequence, the share of firms performing basic activities has increased in the last three years. The trend is rather uniformly spread over the different dimensional classes (Table 10). In the same table it is possible to appreciate the obvious result that basic research share is increasing with the size of the firm.

Conversely, we are able to say something more precise about the Italian market. At an aggregate level, Table 11 shows that the basic research share has almost invariably decreased since 1993, with the exception of 1998 preliminary figures, as far as communication equipment manufacturers are concerned. On the contrary, carriers show a null level of basic research activities. Our hypothesis is that the tendency to shrink the amount of resources allocated to basic activities in the manufacturing sector is the consequence of the turmoil generated by market opening a decade ago. The evidence is confirmed by Table 12, showing the composition of CSELT activities from 1993 on. CSELT is the former incumbent's Research Lab and from 1993 on it has seen its medium-long term activities share reduced from 39% to 31%. We believe that this is the clearest reflection of the fact that CSELT's customers, (mainly Telecom Italia the fixed network operator and TIM, the mobile operator) are redirecting their requirements towards more short term, customer oriented objectives. Indeed, in the 1998 CSELT annual report (CSELT, 1998), this trend is explicitly mentioned as a main pattern of evolution. Therefore, although would not suggest any clear trend in basic research on the side of the operators, we dare interpreting the aforementioned Table 12 as an indication of a general trend, which is being developed in Italy's communication sector. For the sake of completeness, we quote an interesting questionnaire survey, illustrated in (Petroni and Verbano, 1999), whose main results are listed in Table 13, showing that firm's self assessment indicates a generalised drift towards applied activities, and in the telecom sector in particular.

In synthesis, there seems to be a robust indication that the composition of R&D expenditure is indeed evolving towards a reduction of basic activities at least as far as Italy is concerned. Of course, there is no clear indication that this derives directly from the turmoil generated by exogenous shocks and liberalisation in particular. Nevertheless, the pictorial evidence available comforts us in our belief that the market turmoil following liberalisation would bring along a remarkable distortion in the structure of private incentives, inducing firms to unbalance their allocation of resources in favour of applied and development activities. Firms are led to under-invest in basic research or, more radically, to divest their own research units.

The implications on a policy ground, are straightforward. The question is whether or not a sharp decrease in the total amount of basic scientific research carried on in-house may weaken a country's capacity to generate and sustain technological progress in the medium and long term. The answer is, we believe, that the productivity of applied research will indeed be affected when the stock of basic knowledge created by private investment will not be sufficient to feed the innovative process at an appropriate rate. As economic theory would suggest, one major reason for this is certainly to be searched for in the tendency of firms to behave opportunistically, under-investing in a public good (scientific knowledge), and diverting their resources to short-term profit maximising activities. Though, free-riding alone cannot account for the whole story. Besides the problem of the imperfect definition of property rights upon knowledge, it is short-termism that accounts for the rest. This is only partly a structural characteristic of the firms; rather, as we will try to demonstrate, it is embedded in the incentives provided by the competitive regime.

To cut a long story short, our aim is to show how firms, although perfectly aware that no one is willing to contribute to the creation of basic knowledge, will tend to under-invest in such activities. There is not only free-riding at work here, it is the day to day struggle for survival that overwhelms firms and turns the careful planner into a short-sighted economic agent. This is the core issue that we want to elaborate around: when subject to the turbulence following institutional transition, firms will opt for an allocation of R&D resources which might result dynamically inefficient for single firms and for the national system of innovation as a whole. We will also attempt to gain an insight into how elements that are inherent to the technological characteristics of the telecommunications sector, path dependence and rapid obsolescence, may further constraint the allocation of R&D resources within the industry. Our task is therefore to try to shed some light on this aspect from the theory point of view.

The reminder of the paper is structured as follows: the next section reviews the debate on short-termism, section three presents the model, section four illustrates some of the preliminary empirical results obtained, section five concludes.

2 THE DEBATE ON SHORT-TERMISM

The debate on short-termism has long been a crucial theme in economic literature. The main argument is that in specific circumstances managerially controlled firms tend to shorten the time horizon of their investment decisions. Many arguments have been brought forward in favour and against the hypothesis that, when the course of action that is most desirable in the long term is not necessarily the best course of action in the short term, firms tend to privilege the shorter horizon in their decisional process. The debate pivots around the supposed myopia of managerial firms, that some scholars tend to acknowledge whilst other firmly neglect. The debate has been animated by the fact that empirical evidence has ambiguely reinforced the theoretical findings, leaving the central question basically unanswered. In this section we wish to provide a comprehensive review of the different hypotheses that have been formulated in order to explain the (non) emergence of short-termist behaviours in managerial firms. We will discuss such theoretical approaches against the findings of empirical literature. Finally, we point at some very interesting opinions coming from non-academics experts, among which it is possible to depict an almost unanimous consensus about the existence and the economic relevance of short-termism.

We will start by introducing a definition of short-termism from Schumpeter (1942) as reported in Laverty's (1996) exhaustive review of short-termism. Schumpeter argues that a system that at every given point in time fully utilises its possibilities to the best may yet in the long term be inferior to a system that does so at no point in time. It follows that the course of action that is best in the short term may not be the optimal in long run. The shift in the trade-off between short and long term objectives is the core of the short-termist diatribe.

Economic theory has addressed this problem from different angles. The common elements among the different approaches are the emphasis on asymmetric information and the centrality of contestability as a key explanatory variable. We group the various approaches into the following main categories: the diffusion of managerial practices, the emergence of different organisational arrangements, managerial opportunism and stock markets myopia.

First, we discuss the impact of investment appraisal techniques on the time horizon that firms tend to consider relevant to their decisional process. Hayes and Abernathy (1980) argue that the diffusion of discounting techniques should be indicated as the primary cause of the tendency of firms to undervalue projects with higher returns in the long run. The idea is that quantitative analytical tools have a natural bias in favour of the short term, where quantitative data are relatively easier to estimate, and against the long term where quantitative elements are difficult to assess. In other words, the formal discounting techniques bias the perception of the managers towards short term objectives in the sense that such techniques prize analytical detachment and methodological elegance over insight, based on experience. As a result, maximum short-term financial returns have become the overriding criteria for many firm. Hayes and Garvin (1982) address the specific problem of basic R&D spending as an indicator of long term attitude. They argue that the steadily decrease in basic research spending has to be primarly imputed to the rapid diffusion of discounting techniques.

More in general, Morris (1999) highlights the role of sunk costs in determining short termism. He argues that managers tend to underplay the effects of intertemporal externalities (i.e. learning by doing, the creation of new investment opportunities, entry deterrence and so forth) of their investment plans, since these are more difficult to assess in quantitative terms. Therefore they will tend to privilege those investments that are stronger in the dimension of creating an excess of revenue in the shorter term and possibly weaker in terms of additional profits deriving by medium long term strategic advantage, learning by doing, new opportunities and other externalities.

Besides the usual claim that discounting techniques are intrinsically biased towards short term, they also report an interesting view according to which managers tend to deliberately use higher discounting rates in order to protect themselves from unforeseen reductions in cash throw-offs that are triggered by competitors actions and unexpected inflationary increases in investment costs. Furthermore, managers tend to use higher discount factors in order to increase motivation by making targets more difficult to achieve.

In addition, we assist to the cyclical return in fashion of pay-back techniques, which are, by their own definition, biased toward the short term. Though, it is worth considering that the diffusion of such techniques should be regarded as a consequence rather than a determinant of short termism. In fact, an abundant literature testifies that actualisation based discounting techniques are systematically and partially replaced by pay-back based methodologies, in correspondence of periods of cash shortage, which is, on its own account, a determinant of short termism.

The diffusion of the multidivisional firm is the second explanation of short termism that we wish to briefly review. As Chandler (1962) anticipated, the need for corporate head quarters to gain control over the division's managers generates the need to define quantitative performance measures that must be assessed and used in the short term. This, of course, biases the managers' incentives toward fast returns and such peculiar structure of incentives is reflected downward to all the operative segments of the firm. Loescher (1984) contends that the practice of increasing control over the divisions by means of more and more frequent mid-term reports is bound to prune any kind of medium-long term perspective in managers' attitude to investments. Once again, Hayes and Abernathy (1980) illustrate how the increased structural distance between those entrusted with exploiting actual competitive opportunities and those who must judge the quality of their work guarantees reliance on objectively short term criteria.

In a different perspective, Rao's (1998) analysis of the telecommunication industry demonstrates how a structural change in the industry, reflected by the end of the vertical integration model of organisation, results in a vastly different structure of R&D activities, which lose their basic/long term component and become short term oriented. The ICT sector is an excellent example of such trend. The relocation of many research activities to independent market based vendors is progressively and rapidly changing the scope of orientation of the whole industry's research focus.

We now turn to the third dimension of our analysis, namely managerial opportunism. This stream of literature builds on the notion that managers' personal intertemporal choices are suboptimal for the organisation as a whole. The structure of this interpretation is the classic moral hazard one, where information asymmetry and incentive disalignement let an inefficient time horizon emerge in the firms' decisional process. Specifically, managers tend to undertake short terms projects that have a rapid return in order to build up their reputations on which their earnings are based. The argument that managers tend to prefer projects with shorter term rewards in order to enhance their reputations is originally deployed in Narayanan (1985) and Holmstrom (1986). The contribution from Rumelt (1987) pointed to managerial mobility as an important source of short-termism. Within this strand of literature, the model presented by T. Palley (1997), offers an interesting clue to our understanding of short-termism: if managers rewards are based on current profitability, and there is some probability of managerial turnover, then maximising managers will choose projects with an intrinsically lower net present value but yielding higher returns in the short term.

Garvey et al. (1996) reach a counter-intuitive conclusion: when managers are allowed to trade firm's stocks and stock-holders cannot observe their behaviours, these latter will tend to define compensation schemes that are bound to bias managers' actions towards short term targets. Empirical evidence about this aspect is not particularly rich. Bizjack et al. (1993) tested the hypothesis that managers with fewer career commitments (CEO next to retirement) would be more prone to long term investments than managers in their

career rush. Unfortunately they failed to find any kind of evidence. On the contrary, Mannix and Lowestein (1994) conclude that mobility, i.e. a shorter time horizon, would determine a short term oriented strategy.

Finally, we address the issue of stock markets myopia. Under this perspective there are different lines of argument in support of short-termism that should be carefully looked at. The classical one is centred on the existence of asymmetric information in an outsider-control structure in contestable financial markets: managers have no way of conveying to shareholders the benefits of long term strategies and therefore maximise their rewards by choosing short-term objectives.

The core feature of this class of models is therefore the signalling problem. With outside control, the incentive is to rise up the price of shares by boosting profits through long-medium term expenses cut back. This argument is to be found in Stein (1989) who also discusses the key counter-argument to this hypothesis: why investors do not recognise this systematic bias and react consequently? Stein argues that managers are locked in a prisoner's dilemma: although recognising the problem they fail to coordinate, thus behaving short-term. Since the problem is strictly related to the amount of information that investors are able to gain about the firm, the problem is bound to be greater the greater the spread of control.

Empirical evidence is rather puzzling. There is an abundant literature documenting the positive relationship between investments and share prices (Hirschey, 1982, Pakes, 1985, Marsh, 1990). According to Lev (1999) markets consider R&D long term investments as a significant value increasing activity. Miles (1993) demonstrates that investors overestimate discounting factors at a degree which is greater the longer the cash flow has to be awaited for.

Morris (1999) quite rightly finds it difficult to interpret this as an evidence for short-termism. He notes that the fact that longer-term investments do show positive returns in shares does not necessarily imply that myopic behaviour prevented other long-term investments to be financed.

Under this perspective, several authors (Morris,1999 and Laverty, 1996) interestingly note that the pressure to act short term will tend to be more serious in relation to less tangible expenditures such as product and process research and development. Lev (1999) stress the point that R&D evaluation is seriously impeded by the intrinsic intangible nature of the asset, inadequate accounting rules and insufficient disclosure. These elements yield a degree of asymmetry that should in theory exacerbate stock market myopia. Nevertheless, Lev and Sougiannis (1996) present an interesting evidence according to which there is a significant intertemporal association between firms' R&D capital and subsequent stock returns. This is to be interpreted either as a systematic mispricing of the shares or a compensation for an extra-market risk factor associated with long term uncertain projects.

Another stream of interpretation along this line of reasoning, is the take-over threat hypothesis. The idea (Stein, 1988) is that take-over pressure forces managers to sacrifice profitable long term investments in favour of smaller immediate returns. In other words, the threat of take over encourages myopic behaviour of managers. Recent empirical findings have nevertheless weakened Stein's conclusions. Meulbroek et a. (1990) find that anti-takeover provisions and defensive measures exacerbate rather than mitigate managerial myopia. There is an evidence that R&D intensity declines as defensive measures are put at work. Mahoney et al. (1997) demonstrate that the effect of anti-takeover provisions on subsequent long term investments is negative. The common interpretation of this empirical findings is that managers under-invest in long term projects when subtracted by market control through overprotection.

There is an important strand of literature that neglects the existence of short termism. The argument is that competitive markets assure that the long run is properly valued. Specifically, Jensen (1986) argues that managers may be myopic but markets are not, guaranteeing the optimal trade off between short and long term objectives. The implication of this view is that any short termist reaction to boundary conditions should not be regarded as myopic but as an efficient attempt to maximise the total value of the firm.

An alternative explanation is the so called mispricing arbitrage model (Schleifer and Vishny, 1990). The core argument is that arbitrage on mispricing is more favourable the faster price correction occurs. The present value of mispricing arbitrage falls the longer the period to price correction. Since in equilibrium returns form short and long term arbitrage should be equal, long term arbitrage must yield a higher return, i.e. long term investments are more mispriced. Since managers tend to avoid underpricing and its related take-over threat, long term investments are bound to be under-represented in their portfolio. An empirical evidence can be derived from Mahoney et al. (1997) who show how firms that were take-over targets or rumored so cut long term investments more.

Finally, within the broad category of stock market myopia, we consider the so called impatient capital explanation, as proposed by Porter (1992). According to this view, under-investment in long term projects is the result of capital fluidity, i.e. the tendency of financial capital to move rapidly among different firms and projects, on the basis of short term perceptions. As a consequence, managers are forced to invest in short term activities, in order to overcome cash constraints and to capture as much capital as possible.

Outside of academia the debate has been as much intense but it seems to be more univocally oriented. The opinion of managers and commentators seems to converge upon the point that short termism does exist and that it should be given a greater consideration than it actually got in the past. A survey of the UK Times 1000 (Collison et al., 1993) highlighted a common managerial perception according to which investment were evaluated according to profits generated within two years. Most surprinsingly, the vast majority of interviewed managers declared that shareholder would not agree upon an increase in R&D expenses that would drop earning growth below the capital market expectations, rather independently from any actualised measure.

A recent survey of american manufacturers (Thornton, 1998) found that the overwhelming majority of firms pay too much attention to short term performance and should be much more oriented to long term results. In commenting these results for the US government Jacobs (1998) put the hyphen on the role of capital costs as affected by central regulation. Jacobs argues that on a over-national scale excessive regulation on

banks and financial institutions rises capital costs thus harming the willingness of investors to support long term innovative projects.

Nevertheless, the common understanding is that this conclusion cannot be generalised through the industries. Exceptions are to be found in specific industries, like the pharmaceutical one. A survey from BQMA (1994) showed that the capital markets (specifically the City) appraised long term investment in research and development. The survey suggests that there are two detached groups of firms, one which actually suffers from a strong pressure from the City to act short term, another that is rewarded for long term plans. The discriminating factor between the two groups seems to be lay in the intensity of innovation and in the degree of attention paid to communication to shareholders.

This latter view is increasingly legitimated by the recent performances of the so called new economy IPOs, that on average have stunningly increased their stock prices with no (or negative) earnings. As Colvin (1998) reports, Abercrombie and Fitch, Amazon, Netscape and the likes are the living proof that stock markets are indeed ready to prize the prospects of future earnings. Though, this argument should be handled carefully. There is a difference between expectations relative to a whole market and expectations related to a single firm. The problem here seems to be the one of coordination. When the market as a whole does not produce short term results, investors are happy to consider long term plans. But as far as anyone in the market starts producing short term results, the prisoner's dilemma is triggered and firms begin feeling the pressure towards short term.

Many of the non-academic remarks about the issue have been expressed with regard to R&D activities, which are taken as the paradigmatic long term investment. Before briefly reviewing this group of comments, it has to be stressed that it does exist a rather large number of academic commentators (see Laverty, 1996) that rejects the fact that R&D could be taken as a long term investment, on the basis of the consideration that the composition of such activities in actually rather heterogeneous and largely unknown to the majority of investors.

3 THE MODEL

The econometric model presented in this section tests the hypothesis that liberalisation in the telecom sector has caused a relevant mutation in the companies' R&D portfolio. Specifically, we claim that the allocation of resources has drifted in favour of applied and development resources against fundamental research.

As previously discussed, the nature of R&D is so complex and articulated to make any kind of radical distinction between applied and basic research rather implausible. Nevertheless, in order to assess quantitatively the evolution we need to make a rough cut distinction between those results of R&D that are protected by intellectual property rights (i.e. patents) and the results that are obtained and diffused in the form of scientific knowledge (i.e. publications). We will consider the former as a proxy of applied shorter term research and the latter as an indicator of basic research.

The model will pivot around the following hypothesis: the trend in the composition of PTO's R&D activities is significantly modified by the liberalisation of the telecom market. Specifically, we claim that the relative share of basic research activities decreases after (or in anticipation of) the institutional discontinuity. We have tracked the research portfolio of 17 firms from the 15 countries of the European Union plus Switzerland and Norway in a fifteen years time window. The companies are the incumbent PTOs ante liberalisation.

We have used the USPTO database in order to build our patent data set and the IEEE database for publications. The IEEE database includes the vast majority of technical journals related to communication and information technology issues.

3.1 The model for basic research

The model is structured as follows. We try to estimate the relationship between the number of scientific publications (PUB1) as a proxy of basic research against a vector of independent variables describing firms' characteristics and institutional shocks. The variables that we intend to use are (Table 14): WPUB1 the total number of scientific publications in the world, in order to normalise the intensity of scientific activity with respect to the overall world publication trend, the variable SIZE, in order to control for the dimensional factor, BASEPUB1 which accounts for the knowledge base of the firm. Furthermore, we use the binary variable NULLPUB1, which takes value 1 for firms which do not have any publication in the period 1988-1989. This allows us to take into account the fact that the difference between a firm without publications and one with few publications is smaller than the difference between one with few and one with many. We use these variables (BASEPUB1, SIZE) in order to measure firms heterogeneity, following Blundel et al. (1995). They argue that the main source of unobserved heterogeneity lies in the different knowledge stock with which firms enter the sample, i.e. the pre-sample history of innovative effort. Therefore we use dimension (SIZE) and knowledge stock (BASEPUB1) in order to take in account firm specific fixed effects.

The institutional shock is modelled through the variables OMKT, OMKT1, OMKT2. The three variables are three dummies that take a non-null value respectively on the year the market is liberalised, on the year before and on two years before.

Data available are peculiar in the sense that they are small numbers with a large part of null values. Therefore we need to treat them as *count* variables. Empirical literature suggests that the way such variables should be treated is the following: the likelihood that firm *i* in year *t* has n_{it} scientific publications follows a Poisson distribution; more sophisticated models are based on generalisations of the poisson distribution. (Hausman *et al.* 1984; Blundell *et al.* 1995; Crepon e Duguet 1997) but we preliminary limit ourselves to the simplified model. A refined version of the model is being developed and will be presented in a following release.

Therefore we assume:

$$\text{Prob}(PUB1_{it} = n_{it}) = \frac{e^{-\lambda_{it}} \lambda_{it}^{n_{it}}}{n_{it}!}, \qquad (1)$$

$$\lambda_{it} = e^{\beta' x_{it}}$$

where x_{it} is the firm's characteristic vector for $i \in I$, *t*=1990, 1991, …, 1999. In the poisson model the expected value of PUB_{it} is λ_{it}.

As illustrated above, vector x_{it} includes variables $BASEPUB1_{I,}$ and $SIZE_{it}$ respectively measured as the average number of publications and employees in the period previous to liberalisation. Furthermore we use the variable $WPUB1_t$ for the total number of publications in the telecom sector in the world and $OMKT_{it}$ for liberalisation year.

In synthesis, the vector of firm variable will be:

$$x'_{it} = [SIZE_{it}, WPUB1_t, BASEPUB1_i, NULLPUB1_i, OMKT_{it}] \qquad (2)$$

In order to gain a greater flexibility we include in the model the product between $OMKT_{it}$ and $NULLPUB1_i$.

Therefore, the expected value of publications in a given year will be:

$$\lambda_{i,t} = \exp[a + \beta_w \bullet WPUB1_t + \beta_s \bullet SIZE_{i,t} + \beta_b \bullet BASEPUB1_i + \qquad (3)$$
$$+ \beta_n \bullet NULLPUB1_i + \beta_{om} \bullet OMKT_{i,t} + \beta_{nom} \bullet (OMKT_{i,t} \bullet NULLPUB1_i)]$$

Of course, in order to estimate the consistency of the "announcement effect" we have estimated equation (3) having substituted $OMKT_{it}$ with variables $OMKT1_{it}$ e $OMKT2_{it}$.

3.2 Applied research

Model (1) can be rewritten to describe the output of applied research. As previously stated we measure such output with the number of patents in a given year (PAT). In analogy to what described in the previous section, the variables used in the model are listed in Table 15:

PAT is a count variable and the likelihood that firm *i* in year *t* gets m_{it} patent is distributed as follows:

$$\text{Prob}(PAT_{it} = m_{it}) = \frac{e^{-\mu_{it}} \mu_{it}^{m_{it}}}{m_{it}!}, \qquad (4)$$

$$\mu_{it} = e^{\gamma' z_{it}}$$

where z_{it} is a vector of firm's caracteristics, $i \in$ I, t=1985, … 1999. In the Poisson's model μ_{it} is the expected value of PAT_{it}; therefore, after the estimation of the coefficients γ, it is possible to estimate the effects of any component of z_{it} on that value, for any firm in the sample. Again, (see previous paragraph for discussion) we will include in vector z_{it} the variable $BASEPAT_i$, together with $SIZE_{it}$, $WPAT_t$, and $OMKT_{it}$. $BASEPAT_i$ is the average of patents granted over the five years before 1980. Furthermore we include, $NULLPAT_i$, which takes value 1 for firms that do not have any patent in the period 1980-1984 and its product with OMKT.

The vector is therefore:

$$z'_{it} = [SIZE_{it}, WPAT_t, BASEPAT_i, NULLPAT_i, OMKT_{it}]. \qquad (5)$$

The expected value of the number of patents is therefore:

$$\mu_{i,t} = \exp[a + \gamma_w \bullet WPAT_t + \gamma_s \bullet SIZE_{i,t} + \gamma_b \bullet BASEPAT_i + \qquad (6)$$
$$+ \gamma_n \bullet NULLPAT_i + \gamma_{om} \bullet OMKT_{i,t} + \gamma_{nom} \bullet (OMKT_{i,t} \bullet NULLPAT_i)]$$

The same model has been estimated for $OMKT1_{it}$ e $OMKT2_{it}$.

4 Results

Models (1) e (4) have been estimated for the periods 1985-'99 (patents) and 1990-'99 (publications). Therefore, for model (1) we have 170 observations, for model (4) 253 observations.

Results are listed in Table 16 for model (1) and in Table 17 for model (4).

Table 18 and Table 19 illustrate the results of the log-likelihood test that we performed in order to verify the hypothesis that the restriction on OMKT can be accepted. As clear in both models OMKT(0,1,2) contributes significantly to explain the expected value of publications and patents, thus allowing us to reject the restriction.

We can therefore confidently state that liberalisation does influence the trend in the production of scientific and applied knowledge of the firms in our sample.

If we look at the firms' characteristics variable, we see that all variables are significant (0.99) with exception of WPUB1 in the publications model. The coefficients' signs in the extended model give us interesting hints. WPUB1 and WPAT contribute positively to the expected value of the dependent variable, demonstrating that European PTOs have taken advantage by the broadening of the world knowledge base in the sector, both in basic research and applied research. The sign of the variable SIZE is positive in the two models, suggesting, as expected, that dimension exerts a positive effect on research activity at the two levels. The coefficient for BASEPUB1 is positive, implying a direct relationship between the stock of knowledge of the firm and scientific activity, whilst BASEPAT influences negatively the expected value of the number of patents. The coefficient of NULLPAT and NULLPUB is negative, implying that a null research activity in the pre-sample years heavily jeopardise the firm's research and development capacity.

As far as liberalisation is concerned, the effect of the variables OMKT(0,1,2) can be assessed as follows, respectively for publications and patents:

$$\varepsilon_{PUB1} = \left(\frac{\hat{\lambda}_{OMKT=1} - \hat{\lambda}_{OMKT=0}}{\hat{\lambda}_{OMKT=0}}\right) = \exp[\hat{\beta}_{om} \bullet OMKT + \qquad (7)$$
$$+ \hat{\beta}_{nom} \bullet (OMKT \bullet NULLPUB1)] - 1$$

$$\varepsilon_{PAT} = \left(\frac{\hat{\mu}_{OMKT=1} - \hat{\mu}_{OMKT=0}}{\hat{\mu}_{OMKT=0}}\right) = \exp[\hat{\gamma}_{om} \bullet OMKT + \qquad (8)$$
$$+ \hat{\gamma}_{om} \bullet (OMKT \bullet NULLPAT)] - 1$$

This estimates the impact of liberalisation on R&D activities in terms of relative change in the number of publications and patents. As illustrated in Table 20 and Table 21, the three models for basic research evidence a negative impact of the liberalisation date, for firms with a non null publication base. The relative variation is respectively -76,4% for the liberalisation year, -67.06% for the year before liberalisation and –60.62% for two years before. This confirms our hypothesis that the liberalisation year narrows the relative share of resources dedicated to fundamental research.

On the other side, the models for applied research evidence a positive impact of the liberalisation date. The relative variation is respectively +24.62% for the liberalisation year, +30.01% for the year before and +48.08% for two years before. This witnesses an incentive for PTOs to broaden the share of applied activities in coincidence or in prospect of the forthcoming liberalisation. Specifically, as far as patents are concerned, the "announcement effect" seems to be particularly relevant. This can be probably explained with the augmented need to protect technological innovation when the market is opened up.

The results presented in this paper are preliminary, in the sense that these are based on a relatively simplified version of a count data model. A more elaborated version of the model is currently being developed. Furthermore we are trying to broaden our data set to the rest of the world, including United States and Japan.

5 DISCUSSION AND CONCLUSIONS

This paper tries to shed some light on the role of industrial turmoil in determining the composition of R&D expenses. Specifically, we study the effect of liberalisation on the relative share of resources allocated to basic and applied activities. The issue has found scarce attention in the literature until now; on the contrary we believe that its relevance should not be played down in any serious debate on the effects of liberalisation.

Our research question pertains to the balance between basic (long term) and applied (short term) activities. We have set our model in the telecommunication industry framework, since in this specific sector we observe controversial and puzzling evolutionary profiles. The industry has traditionally sustained its exceptional rate of technological advance thanks to long term investments in basic and scientific knowledge. The question is, therefore, whether the new competitive setting will turn up to be equally conducive to innovation and technical change. We argue that this might not be the case.

Results of our model can be summarised as follows. We have proved that on the year of liberalisation, the incumbent PTOs have significantly reduced its publications output, that we take as a proxy of basic activity. In addition, we have an evidence that there is an "announcement effect", since the publication activity starts its decline two years before the liberalisation date. On the contrary, patenting activity has been boosted by forthcoming liberalisation. Specifically, we have a strong effect in a two year anticipation and a mitigated effect on the two following years. In both models, the described effect is relevant for PTOs with a strong consolidated publications (patents) base. On the contrary, the effect is weak for firms which do not have a consolidated scientific or technological tradition.

We hasten to say that the merit of our effort is to take innovation back at the very heart of the debate on liberalisation, broadening the traditional R&D-intensity perspective. Besides this latter aspect, which by the way is still rather puzzling, there is a very important question about the composition of R&D efforts. Only a balanced profile of long and short term research investments will guarantee the industry and the national systems of innovation an appropriate rate of technological progress.

The issue is crucial to policy makers. The effects will become manifest, by definition, in the medium-long term, when it might be far too late to design any kind of policy to mitigate the effects of a collapse in the industry's knowledge base. We address this comment to countries, just like Italy, that are followers in the innovation race and might therefore be tempted to direct their efforts uniquely to the exploitation of technological knowledge created elsewhere. It emerges from our work that this strategy is myopic and is likely to lock the national innovation system in a utterly vicious trajectory.

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TABLES

Table 1 – R&D Expenses in world telecommunication companies (carriers)

	1996	1995	1994	1993	R&D% of sales 1996
UK					
British Telecom	282,000	271,000	265,000	233,000	2.0
Vodaphone	27,100	20.300	16,815	14,527	1.9
Securicor	2,500	2,000	0	0	0.2
Orange	700	n/a	n/a	n/a	0.1
USA					
AT&T	373,985*	2,172,617	1,817,332	1,793,373	1.2
GTE	71,291	80,056	81,225	78,887	0.6
Nynex	95,308	163,092	93,921	77,485	1.2
Other countries					
NTT, Japan	1,601,407	1,580,408	1,563,563	1,487,437	4.0
Telia, Sweden	118,872	31,759	38,340	43,561	3.2
CTN, Spain	95,105	87,701	52,912	55,607	0.6

Source: The UK R&D Scoreboard 1997, Department of Trade and Industry (Figures in British Pounds)
* Not including Lucent

Table 2 – R&D % of sales in the past years (carriers)

	1996	1991	1987
NTT, Japan	4.0	4.1	3.8
British Telecom, UK	2.0	1.9	2.1
AT&T, USA	1.2*	n/a	7.3

Source: Fransmann (1994) and The UK R&D Scoreboard 1997, Department of Trade and Industry

* Not including Lucent

Table 3 – R&D % of sales in the past years (manufacturing)

	1994	1995	1996	1997	1998
Cisco Systems	n.a	5.3	5.5	5,8	n.a
Ericsson	19.9	19.4	17.7	15.9	n.a
Lucent	n.a	n.a	9.8	11.8	12.0
Motorola	8.4	8.1	8.6	9.2	n.a.
Nokia	6.1	6,6	8.8	8.7	n.a.
Nortel	13.0	14.8	14.1	13.9	n.a
Matsushita	5.3	5.3	5.6	6.1	n.a.
Racal Electronics	n.a.	7.3	6.8	6.7	n.a.
Siemens	8.9	8.2	7.7	7.7	n.a.
3COM	n.a.	10.4	10.0	10.7	n.a.

Source: Pontarollo (1998)

Table 4 - Total (company, Federal, and other) industrial R&D funds as a percent of net sales in R&D- performing companies in the United States

	Electrical equipment	Communication equipment	Communications
SIC code	**36**	**366**	**48**
1987	8,2	10,2	n.a.
1988	7,5	10,7	n.a.
1989	7,3	11,6	n.a.
1990	6,5	10,0	n.a.
1991	6.5	(D)	n.a.
1992	5,6	(D)	n.a.
1993	6,2	(D)	n.a.
1994	5,9	(D)	n.a.
1995	6,0	(D)	(D)
1996	6,7	(D)	(D)
1997	6,2	(D)	(D)

Source: National Science Foundation/SRS, *Survey of Industrial Research and Development*. Arlington, VA: National Science Foundation, 1989,1990,1991,1994,1997

(D) not available due to disclosure clause

Table 5 - R&D Intensity in Italy

	Communications Equipment	Post and Communications
1993	9.50%	0.37%
1994	10.00%	0.29%
1995	9.03%	1.16%
1996	8.36%	1.29%
1997 Prelim.	7.17%	3.31%
1998 Prelim.	7.14%	n.a.

Our elaboration on:
OECD, 1995, 1997, 1999, *Communications Outlook*, OECD: Paris
ITU, 1997, 1998, *World Telecommunications Development Report*, ITU: Geneve
ANIE (Associazione Nazionale Imprese Elettrotecniche ed Elettroniche), 1999, *Rapporto Annuale 1999*

Table 6 - National expenditures for total and basic R&D activities performed by the US industry [millions of constant 1992 dollars]

Year	Total R&D	Basic Research	Basic research share
1970	57.568	1.852	3,22%
1971	55.468	1.733	3,12%
1972	56.713	1.653	2,91%
1973	58.526	1.682	2,87%
1974	57.723	1.687	2,92%
1975	55.645	1.606	2,89%
1976	58.514	1.681	2,87%
1977	60.813	1.761	2,90%
1978	63.276	1.848	2,92%
1979	67.064	1.907	2,84%
1980	71.593	1.996	2,79%
1981	76.343	2.236	2,93%
1982	81.423	2.530	3,11%
1983	87.009	2.877	3,31%
1984	96.199	3.255	3,38%
1985	104.864	3.477	3,32%
1986	106.629	4.877	4,57%
1987	108.543	5.033	4,64%
1988	110.207	4.835	4,39%
1989	111.297	5.370	4,82%
1990	114.700	4.943	4,31%
1991	117.833	7.579	6,43%
1992	116.757	6.528	5,59%
1993	112.466	6.262	5,57%
1994	111.707	6.198	5,55%
1995	120.481	5.168	4,29%
1996	129.181	6.803	5,27%
1997 prelim.	133.751	6.827	5,10%
1998 prelim.	142.594	6.849	4,80%

Table 7 - Top 10 “biggest” problems for technology leaders

(Percentages of total votes)

Survey item	1993	1994	1995	1996	1997
Number of total responses	248	193	258	242	223
Managing R&D for business growth	NA	NA	5.9	10.0	17.0
Balancing long-term/short-term R&D objectives/focus	**10.1**	**12.2**	**11.0**	**12.1**	**14.7**
Integration of technology planning with business strategy	11.0	10.2	7.4	11.2	13.0
Making innovation happen	NA	NA	7.8	9.5	10.3
Management of global R&D	3.8	2.9	3.5	4.5	5.8
Leadership of R&D within the corporation	1.7	3.2	2.3	4.2	4.0
Measuring R&D productivity/effectiveness	15.2	15.1	11.5	11.8	4.0
R&D portfolio management	4.2	5.0	4.5	4.5	4.0
Selling R&D internally or externally	5.0	3.1	2.6	4.2	4.0
Information technology	NA	NA	NA	NA	3.1
Percent of responses (top 10)	40.9	39.5	56.5	72.0	79.9

NA = not asked

SOURCE: Industrial Research Institute, Member Company Representatives, “The ‘Biggest’ Problems Technology Leaders Face,” Research Technology Management, September-October, 1997.

Table 8 -National expenditures for total and basic R&D activities performed by the US industry

	Funded by the federal governmentand industry			Funded by The industry		
Industry	**Comm.Equip.**	**Electr.Equip.**	**Comm.**	**Comm.Equip.**	**Electr.Equip.**	**Comm.**
Basic Research						
1989	(D)	(D)	n.a.	(D)	544	n.a.
1990	(D)	558	n.a.	(D)	534	n.a.
1991	(D)	504	n.a.	(D)	495	n.a.
1992	(D)	(D)	n.a.	(D)	313	n.a.
1993	(D)	(D)	n.a.	(D)	364	n.a.
1994	(D)	(D)	n.a.	(D)	388	n.a.
1995	(D)	(D)	(D)	56	240	(D)
1996	(D)	(D)	(D)	18	531	(D)
1997 Prelim.	(D)	954	(D)	148	921	(D)
Total R&D						
1989	10,539	16,929	n.a.	5,820	11,641	n.a.
1990	10,770	17,723	n.a.	5,932	12,131	n.a.
1991	10,444	17,279	n.a.	6,232	12,455	n.a.
1992	(D)	13,360	n.a.	3,381	9,516	n.a.
1993	(D)	13,349	n.a.	3,954	11,682	n.a.
1994	(D)	15,338	n.a.	4,939	13,537	n.a.
1995	(D)	18,751	(D)	3,845	17,060	4,756
1996	(D)	22,498	(D)	4,359	20,356	3,970
1997 Prelim.	(D)	24,585	(D)	7,377	22,747	1,884
Basic Research Share						
1989	-	-	-	-	4.67%	-
1990	-	3.15%	-	-	4.40%	-
1991	-	2.92%	-	-	3.97%	-
1992	-	-	-	-	3.29%	-
1993	-	-	-	-	3.11%	-
1994	-	-	-	-	2.87%	-
1995	-	-	-	1.46%	1.40%	-
1996	-	-	-	0.41%	2.61%	-
1997 Prelim.	-	3.88%	-	2.01%	4.05%	-

n.a.: not available; (D): data have been withheld to avoid disclosing operations of individual companies.

Comm.Equip.: Communication Equipment - SIC Code 366

Elect.Equip.: Electrical equipment (Radio and TV receiving equipment, Communication equipment, Electronic components, Other electrical equipment) - SIC Code 36

Comm: Communications – SIC Code 48

SOURCE: National Science Foundation/SRS, *Survey of Industrial Research and Development*. Arlington, VA: National Science Foundation, 1989,1990,1991,1994,1997

Figure 1 – Absolute number of firms performing basic R&D

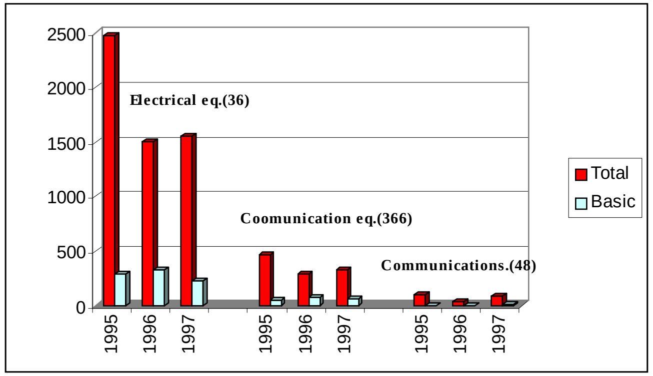

Figure 2 – Share of firms performing research

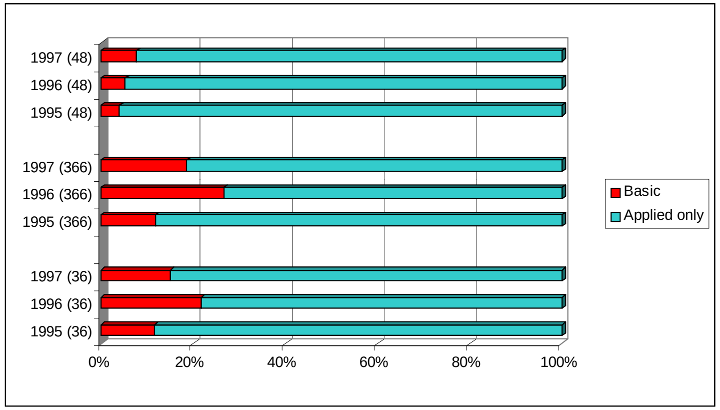

Table 9 - Number of companies conducting industrial basic research and total number of R&T performing companies

	1993			1994			1995			1996			1997		
Industry	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share
Electrical eq.(36)	2169	D	D	3025	235	7.88	2475	288	11.63	1498	325	21.69	1548	232	14.98
Communicat. eq. (366)	D	D	D	174	24	13.79	466	55	11.80	289	77	26.64	322	60	18.63
Communucation (48)	D	D	D	D	D	D	99	4	4.04	38	2	5.26	90	7	7.77

Table 10 – Number of companies conducting industrial basic research and total number of R&T performing companies, by industry and size of company. Source: National Science Foundation/SRS, *Survey of Industrial Research and Development* 1993,1994,1995,1996,1997

Fewer than 500 Employees

	1993			1994			1995			1996			1997		
Industry	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share
Electrical eq. (36)	1941	393	20.25	2787	198	7.10	2195	257	11.72	1178	269	22.84	1217	185	15.20
Communicat. eq. (366)	442	D	D	125	18	14.40	404	47	11.63	232	69	29.74	255	53	20.78
Communucation (48)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	58	2	3.45	22	0	0.00	24	4	16.67

500 to 999 Employees

	1993			1994			1995			1996			1997		
Industry	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share
Electrical eq. (36)	90	11	12.22	91	10	10.99	111	7	6.31	155	25	16.13	140	16	11.43
Communicat. eq. (366)	D	D	D	18	2	11.11	32	3	9.38	27	4	14.81	25	2	8.00
Communucation (48)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2	0	0.00	2	0	0.00	2	1	50.00

1000 to 4999 Employees

	1993			1994			1995			1996			1997		
Industry	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share
Electrical eq. (36)	111	23	20.72	111	17	15.32	133	15	11.28	126	21	16.67	136	17	12.50
Communicat.eq. (366)	23	D	D	25	3	12.00	24	4	16.67	23	3	13.04	23	3	13.04
Communucation (48)	n.a	n.a.	n.a.	n.a.	n.a.	n.a.	27	1	3.70	3	1	33.33	4	1	25.00

5000 to 9999 Employees

	1993			1994			1995			1996			1997		
Industry	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share
Electrical eq. (36)	8	D	D	13	3	23.08	15	5	33.33	18	5	27.78	33	7	21.21
Communicat. eq. (366)	0	0	0.00	1	0	0.00	2	0	0.00	4	0	0.00	16	1	6.25
Communucation (48)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1	0	0.00	1	0	0.00	51	0	0.00

10000 to 24999 Employees

	1993			1994			1995			1996			1997		
Industry	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share
Electrical eq. (36)	9	0	0.00	13	2	15.38	9	0	0.00	12	3	25.00	11	3	27.27
Communicat. eq. (366)	D	0	D	2	0	0.00	2	0	0.00	1	0	0.00	0	0	0.00
Communucation (48)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0	0	0.00	0	0	0.00	0	0	0.00

25000 or more Employees

	1993			1994			1995			1996			1997		
Industry	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share	Total	Basic	Share
Electrical eq. (36)	10	D	D	10	5	50.00	12	4	33.33	9	2	22.22	11	4	36.36
Communicat. eq. (366)	D	0	D	3	1	33.33	2	1	50.00	2	1	50.00	3	1	33.33
Communucation (48)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	11	1	9.09	10	1	10.00	9	1	11.11

Table 11 – National expenditures for total and basic intra-muros R&D activities performed by the Italian industry (funded by the government and industry)

	Communications Equipment	Post and Communications	All Industries
Basic Research			
1993	41239	0	246470
1994	43982	0	254836
1995	36813	0	272398
1996	36960	0	275368
1997 Prelim.	32750	0	285488
1998 Prelim.	47250	0	335858
Total R&D			
1993	1256885	47430	9450383
19 94	1413234	36728	9206050
1995	1356997	142403	9540714
1996	1363048	193108	10246771
1997 Prelim.	1427252	464009	11369609
1998 Prelim.	1482491	521766	12081264
Basic Research Share			
1993	3,28%	0,00%	2,61%
1994	3,11%	0,00%	2,77%
1995	2,71%	0,00%	2,86%
1996	2,71%	0,00%	2,69%
1997 Prelim.	2,29%	0,00%	2,51%
1998 Prelim.	3,19%	0,00%	2,78%

Source: **ISTAT, *Statistiche sulla ricerca scientifica e l'innovazione tecnologica 1998*, Roma, 1998 (millions of italian current Lira)**

Table 12– The Composition of CSELT R&D Activities

	1993		**1994**		**1995**		**1996**		**1997**		**1998**	
Short term	94,2	60,7	114,1	65,5	123,1	64,4	147,6	64,9	185	69,0	179,9	68,0
Medium-long term	61,2	39,3	59,9	34,5	68,1	35,6	80	35,1	83,1	31,0	84,8	32,0
Total	155,4	100	174	100	191,2	100	227,6	100	268,1	100	264,7	100

Source: CSELT Annual reports (1994-1998) – (Figures in Italian Lira, thousands of millions)

Table 13 – The shift towards applied research

	Shift towards basic research		**Shift towards applied research**	
	All industries	**Telecom**	**All industries**	**Telecom**
Strongly disagree	39	3	1	0
Disagree	29	1	7	1
Uncertain	5	0	12	0
Agree	5	0	36	2
Strongly agree	2	0	24	1

Source: Petroni and Verbano (1999)

Table 14 : **variables in the basic research model.**

VARIABILI	DEFINITION	SOURCE
PUB1	Number of PTO's publications	IEEE/IEE
WPUB1	Number of world's publications	IEEE/IEE
SIZE	Number of PTO's employees	OECD
BASEPUB1	Technolgy knowledge base (before 1990)	IEEE/IEE
NULLPUB1	Dummy variable for technology base NULLPUB1= 1 if BASEPUB1= 0	IEEE/IEE
OMKT	Dummy variable for liberalisation year OMKT= 1 when market is liberalised	ESIS
OMKT1	Dummy variable for liberalisation year. OMKT1= 1 if market is liberalised the following year	ESIS
OMKT2	Dummy variable for liberalisation OMKT2= 1 if market is liberalised after two years	ESIS

Table 15: **variables in the applied research model**

VARIABLES	DEFINITION	SOURCE
PAT	Number of patents of PTO	USPTO
WPAT	Number of patents in the world	USPTO
SIZE	Number of PTO'S employees.	OECD
BASEPAT	Technological base before 1985	USPTO
NULLPAT	Dummy variable for technological base NULLPAT= 1 if BASEPAT= 0	USPTO
OMKT	Dummy variable for liberalisation OMKT= 1 if market is liberalised	ESIS
OMKT1	Dummy variable for liberalisation. OMKT1= 1 if market is liberalised in the following year	ESIS
OMKT2	Dummy variable for liberalisation OMKT2= 1 if market is liberalised after two years	ESIS

Table 16: Results from model (1)

Observation: 170	Variable	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
		Restricted model		*Extended models*					
	Constant	0,67	*0,99*	-1,19	*0,99*	-0,29	*0,93*	-0,08	*0,99*
	WPUB1	0,00	*0,43*	0,21	*0,99*	0,10	*0,99*	0,09	*0,99*
	SIZE	0,01	*0,99*	0,01	*0,99*	0,01	*0,99*	0,01	*0,99*
	BASEPUB1	0,09	*0,99*	0,15	*0,99*	0,14	*0,99*	0,12	*0,99*
	NULLPUB1	-2,28	*0,99*	-2,85	*0,99*	-3,07	*0,99*	-4,42	*0,99*
No lag	OMKT	-	-	-1,45	*0,99*	-	-	-	-
	OMKT*NULLPUB1	-	-	2,04	*0,99*	-	-	-	-
one year lagged	OMKT1	-	-	-	-	-1,11	*0,99*	-	-
	OMKT1*NULLPUB1	-	-	-	-	2,48	*0,99*	-	-
two years lagged	OMKT2	-	-	-	-	-	-	-0,92	*0,99*
	OMKT2*NULLPUB1	-	-	-	-	-	-	3,67	*0,99*

Table 17: results from model (5)

Observations : 253	Variable	Coeff.	Confid.	Coeff.	Confid.	Coeff.	Confid.	Coeff.	Confid.
		Restricted model		Extended model					
	Constant	1,33	0,99	1,64	0,99	1,63	0,99	1,65	0,99
	WPAT	0,08	0,99	0,06	0,99	0,06	0,99	0,05	0,99
	SIZE	0,01	0,99	0,01	0,99	0,01	0,99	0,01	0,99
	BASEPAT	-0,05	0,99	-0,04	0,99	-0,04	0,99	-0,04	0,99
	NULLPAT	-3,17	0,99	-4,53	0,99	-4,61	0,99	-4,60	0,99
No lag	OMKT	-	-	0,22	0,99	-	-	-	-
	OMKT*NULLPAT	-	-	2,41	0,99	-	-	-	-
One year lagged	OMKT1	-	-	-	-	0,26	0,99	-	-
	OMKT1*NULLPAT	-	-	-	-	2,30	0,99	-	-
Two years lagged	OMKT2	-	-	-	-	-	-	0,39	0,99
	OMKT2*NULLPAT	-	-	-	-	-	-	2,10	0,99

Table 18: likelihood test for basic research model

	Log-likelihood, $\ln \hat{L}$		ν^: likelihood ratio degrees of freedom: 2 c:| Prob[χ^2 (2)<c]=0,99		
	Restricted model, R	Extended model, E	ν	c	Restriction
No lag (OMKT)	-526,04	-429,55	192,98	10,60	Not accepted
One year lagged (OMKT1)	-526,04	-462,89	126,30	10,60	Not accepted
Two years lagged (OMKT2)	-526,04	-467,24	117,61	10,60	Not accepted

$$\hat{\nu} = -2 \cdot \left[\ln \hat{L}_R - \ln \hat{L}_E \right] \sim \chi^2 (2)$$

Table 19: likelihood test for the applied research model

	Log-likelihood, $\ln \hat{L}$		ν^: likelihood ratio Degrees of freedom: 2 c:| Prob[χ^2 (2)<c]=0,99		
	Restricted model, R	Extended model, E	ν	c	Restriction
No lag (OMKT)	-713,00	-613,74	198,51	10,60	Not accepted
One year lagged (OMKT1)	-713,00	-623,26	179,47	10,60	Not accepted
Two years lagged (OMKT2)	-713,00	-626,57	172,85	10,60	Not accepted

$$\hat{\nu} = -2 \cdot \left[\ln \hat{L}_R - \ln \hat{L}_E \right] \sim \chi^2 (2)$$

Table 20: effect of liberalisation on publications

ε see (7)	*No lag*	*One year lagged*	*Two years lagged*
Firms with publications stock (NULLPUB1=0)	-76,47%	-67,06%	-60,26%

^ $\varepsilon = e^{+\beta} - 1$

Table 21: **effect of liberalisation on patents**

ε see (8)	*No lag*	*One year lagged*	*Two years lagged*
Firms with patents stock (NULLPAT=0)	24,62%	30,01%	48,08%

^ $\varepsilon = e^{+\gamma} - 1$