A short introduction

One of the central tenets of the “new economics” of growth is that innovation is critical for productivity increases and growth. Yet the micro-foundations of this argument are underdeveloped. An important task is therefore to examine the way in which the productivity of companies or industries is affected by R&D, patents, innovation and other related factors.

This network has developed a wide range of studies examining the relationships between productivity, technology, innovation, and economic performance. We can classify these studies in four groups:

- Studies on the relationships between aggregate productivity (typically at the level of countries or industries) and technological innovation or R&D
- Studies on the relationships between firm-level productivity, investment, R&D, and other variables
- Studies focussing on the so-called “computer productivity paradox”, notably the relationships between computer diffusion and productivity
- Other miscellaneous studies linking variables like innovation, R&D, patents, productivity to several institutional and economic factors.

We shall review these in turn.

Aggregate productivity studies

In the 1998 Urbino conference of this network Zvi Griliches presented a preliminary draft of his Kuznets Memorial Lectures. Particularly, he focused on section 6 of his Lectures on R&D and the productivity slowdown (Griliches, 1998).

Griliches examined the existing evidence on the productivity slowdown, and discussed various explanations. He noted that there are three major explanations. The first one is that the upturn in productivity growth is in fact around the corner,
but it takes time for the big changes produced by the new computer and
biotechnology revolutions to work themselves through the system. The second
explanation is that the effects of these technologies are long-term. Hence, it takes
time before we can see them in the statistics. The third explanation is that we
simply do not know how to measure them. Griliches argued that measurement
errors are probably not the whole thing, but nonetheless he emphasized that we do
have serious measurement challenges ahead of us – e.g. how to account for
productivity growth in services. He is also less convinced by the other two
explanations. After all, he suggested, the computer revolution has been around
for 20-30 years now.

In the Urbino conference this spurred a lively debate. Particularly, Paul David,
whose “Computer and Dynamo” paper (David, 1990) had argued in favour of the
first explanation, did not disagree with the need for better measurement.
However, he noted that the problem is not how long does it take for the new
technologies to induce productivity growth, but whether economies and societies
more generally have been able to introduce complementary organizational
revolutions. These are crucial in order to relax some of the constraints to
productivity growth associated with computers and computer networks (e.g.
telework).

The network produced a few other papers about aggregate productivity effects.
Griffith, Redding and Van Reenen (1998) examined empirically the determinants
of TFP growth in two-digit OECD industries in eleven OECD countries since
1970. They investigated the roles of R&D, education and trade in stimulating
productivity growth directly and indirectly through technology transfer from the
USA. They found that R&D is important in technology transfer, especially for
smaller countries. For larger countries (Britain, France, Germany and Japan),
R&D has a more direct effect through generating innovations. Moreover, they
found that for these countries education facilitates productivity convergence to the
USA.

In a related paper, Carlin, Glyn and Van Reenen (1998) examined the
determinants of export market shares in a long panel of twelve manufacturing
industries across fourteen OECD countries. They found that both relative labour
costs and embodied technology are important, but the residual country-specific
trends appear to be linked to “deep” structural features of the economies such as
human capital investment and national ownership patterns.

The network also developed a few papers showing that investment or productivity
growth are related to specific features of industry structure. Particularly, they can
be associated with vertical specialization and division of labour and the role of an
upstream sector of technology producers or knowledge-intensive business firms or
industries.

Bresnahan and Gambardella (1998) developed a model that shows that the rise of
a vertically specialized sector producing general-purpose technologies (GPT) is
associated with the number of potentially different application of the GPT in an
economy. By contrast, an economy featuring users of larger size will develop
dedicated technologies produced in-house by the users themselves. Implicit in
their analysis is that the expansion of the GPT sector can lead to greater
investments by the downstream industries. Arora, Fosfuri and Gambardella (1998) empirically tested a similar proposition. Using data on the supply of chemical process engineering services by specialized chemical engineering firms, they showed that the expansion of the upstream sector leads to greater downstream investments in chemical plants.

The importance of division of labour is confirmed by Katsoulacos and Tsounis (1998) who examined the effects of information intensive business services (BS) on productivity growth in the Greek economy. Among other things, they found that: a) there is a strong association between the co-evolution of BS with communication services in the Greek economy; b) there is a correlation of the rates of growth of BS with the rates of growth of communication services; c) BS play an important role in explaining the rates of growth of TFP in the Greek economy; d) BS can be thought as a factor of production since they are important in explaining the variance of value-added in Greece, along with capital and labour.

One interesting implication of these studies is that what we normally label technological spillovers can in fact be produced by mechanisms based on the intermediation of an upstream industry. Put differently, spillovers may not just be “in the air”, but they require well defined institutions to work. (See also Zucker et al., 1998). Policy implications would follow quite naturally.

**Firm-level patents, investments, productivity and R&D**

One important set of studies developed by this network focused on the relationships between variables like patents, R&D, investment and various measures of economic performance (productivity or else) using firm-level data. For instance, Hall and Mairesse (1998) have continued their research examining the progress in econometric modelling of investment at the micro-level. Their work compares the results based on the econometric techniques and investment models for panel data employed by Eisner and Oudiz 20 years ago to the econometric techniques and investment models representing at least a part of the the state-of-the art today.

Hall, Jaffe and Trajtenberg (1998) continued the tradition of looking at the effects of patents and innovation variables on the market evaluation of firms. Particularly, in this paper they introduce a citation-weighted measure of patent stocks to account for the knowledge asset of firms, and explore the impact of this variable on the market value of a comprehensive set of US manufacturing companies. This is an important innovation with respect to previous studies which use R&D or patent counts in market value equations. But R&D is an input, and patent counts do not account for the fact that the importance of patents as a measure of innovation is very skewed. Patent citations can correct at least in part this problem. They find that their measure of knowledge asset does explain part of the market value of firms, and it contains information beyond the usual R&D or patent measures.

The network also organized a conference (Paris 18-19, 1998) focused on empirical analyses of Innovation Survey Data, and particularly of the Community
Innovation Surveys (CIS). Most studies in this conference dealt with one or two of the following issues: the determinants of innovation; the propensity to patent an invention; the links between innovation (and spillovers) and productivity growth. The conference also offered the opportunity to clarify two aspects about the use of CIS. First, there is a need to adopt more homogeneous frameworks across studies to get comparable conclusions across countries. Second, CIS provides information at a given point in time. This means that the intrinsic dynamic features of technological progress are missing.

The main results of these studies can be summarized as follows:⁴

1) *The determinants of innovation*

- There is a sector-specific nature of patent disclosure and a significantly greater use of this source by larger than smaller firms.
- Developing capabilities in different areas (such as technological capabilities and marketing competencies), and not just in R&D, is a prerequisite for innovation.
- Intermediate levels of competition are more conducive to innovation than monopolistic or perfect competition.
- Interindustry spillovers (i.e., complementarity between firms) increase the propensity to form RJVs.
- The probability to innovate is higher in capital intensive firms and in firms with export activities.

2) *The propensity to patent an invention*

- Patents are not seen by firms as a very efficacious means of direct protection of the inventions, but are extensively used as a tool for blocking, use in negotiations, and prevention of suits.
- Internal sources are extremely important but become relatively less important with firm size.
- Smaller innovators have less confidence in patent protection, but when they apply for patents, they tend to have higher number of patent applications per invention than larger firms.

3) *The links between innovation (and spillovers) and productivity growth*

- Intrat驾校 spillovers are greater and the appropriability of rents to innovation are weaker in Japan than in the US.
- There are several different dimensions to technological change within a firm and the use of a single index would hide some of these.
- Technological innovations lead to an increase in labor and foster productivity gains, profitability and wages.
- Agglomeration economies and technological spillovers are, at best, a modest contribution to TFP growth.

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The patterns of international flows of information and technology are linked with international trade, but also with the magnitudes of the potential markets.

The network also developed some methodological studies on the relationships between R&D, innovation and firm growth. This reflects some disenchantment with existing econometric methods of examining the effects of innovation on firm performance. Klette and Griliches (1997) put forward a more general theoretical framework building on endogenous growth theory and Gibrat's Law of firm growth. They argue that it can account for more of the stylised micro-facts than the standard augmented production function approach. Research on this issues has continued throughout the programme and has been the subject of lively debate in the Summer conferences in Chania and Urbino.

Harhoff (1997) is another attempt to empirically test a structural model of R&D investment. The paper develops an oligopoly model of innovation and applies it to data from the Mannheim Innovation Panel. The model circumvents the need for market share and price elasticity data which typically can only be determined with measurement error and are therefore a major source of misspecification. The regression results suggest that access to sources of information is an important determinant for the firm’s R&D activity. Endogenous protection mechanisms such as lead time, design complexity, etc. are important determinants of overall innovation expenditures, but not for R&D specifically. If legal protection mechanisms (such as patents) are effective, they exert a positive effect on R&D spending. Firm-specific financing conditions also affect the innovation activity of the firm.

On a more econometric note, many of the problems in examining the effects of R&D on firm performance stem from the fact there is relatively little variation over time in R&D flows at the firm level. It is therefore difficult to disentangle whether good performance in firms stems from their research efforts or whether R&D and performance are jointly determined by some unobserved factor like organisational quality. Attempts to improve existing GMM methods to account for this have been proposed and implemented by Blundell and Bond (1997), and Klette and Johansen (1997). A good overview of some of the techniques was offered by Arellano (1997) in the Madrid workshop. Currently, existing software is being re-written to handle some of these recent developments.

Computers and Productivity

As hinted by Griliches in his Kuznet Lecture, and noted by Robert Solow’s famous paradox that “one can see computers everywhere except in the productivity figures”, the question of the relationships between information technology and productivity growth has become a crucial one. This network developed several studies on this issue, and organized a joint NBER-CREST conference on this topic (Nice, June 22-23, 1998).

One of the reasons why computers may not show up in the productivity figures may have been the over-emphasis on macro-economic aggregates. Examining micro data many studies have started to uncover important productivity effects.
For example, Greenan and Mairesse (1998) made a first attempt to explore the relationship between computer use and productivity in French manufacturing and services industries. They matched information on computer utilization in the workplace collected at the employee level in the years 1987, 1991 and 1993, with information on firm productivity, capital intensity and average wage available at the firm level. They found coherent and persuasive evidence that the computer impacts on productivity are positive and that the returns to the firm should at least be in the same range as the returns to the other types of capital. They also made the general point that econometric studies of the firm can be effectively and substantially enriched by using information collected from workers.

Licht and Moch (1997) developed a similar study on the use of information technology (IT) in Germany. They advanced two explanations for the computer productivity paradox, using two newly available datasets for the German service sector. They first showed that investment in IT has a stronger effect on the quality of services than on the productivity of the IT-using firm. This suggests that mismeasurement of the quality of new products and processes is one important reason for the inability to uncover the productivity effect of IT. Second, they showed that especially PCs (as opposed to mainframes) and the most recent generation of IT are a source of productivity growth. Thus, the type of IT that a firm uses is more important for productivity growth than its quantity. This also suggests that in order to realize the benefits from IT investment entirely, firms have to undergo a large restructuring of their business functions. As a conclusion, Licht and Moch (1997) seem to indicate that Griliches’ emphasis on mismeasurement and David’s suggestion of the lack of complementary reorganizations are both potential explanations of the problem.

The relationships between computers and productivity have also been the subject of an extensive debate at the NBER-CREST conference in Nice, where several economists were asked to discuss their past research and experience on this topic. Among others, one issue that was raised was that even if new technologies pose important problems of statistical measurement, the origin of the productivity paradox is likely to be mainly an economic one. While initial investments in computers were primarily directed at automation of repetitive, labor intensive tasks, information and communication technology (ICT) investments today are disproportionately directed at enabling new ways of delivering value to customers though new ways of organizing work internally as well as new approaches to interacting with customers and suppliers.

Brynjolfsson (1998) examined a variety of empirical evidence to argue that ICT improve productivity by enabling complementarity organizational innovations. Considering numerous case studies, exploring large sample statistical evidence and examining studies that provide direct measurement of organizational complements, he concluded that, while there are strengths and weaknesses in all these individual studies, they paint collectively a very compelling picture where organizational complements play a critical role in enhancing ICT productivity.

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2 On the use of measures related to computers or IT drawn from the CIS innovation surveys, to explain productivity or the research intensity of firms, see also Harhoff (1997) and Crépon et al. (1998).
The conference also debated other aspects about ICT, and particularly their effects on employment and wages. Chennels and Van Reenen (1998) surveyed the evidence on the effects of technical change on skills, wages and employment by examining the micro-econometric evidence at the industry, firm, plant and individual levels. They showed that there is a strong effect of technology on skills in the cross section which appears reasonably robust to various econometric problems. They also concluded that there is an effect on wages in the cross section, which is not robust, however, to endogeneity and fixed effects, and that there is not a clear relationship between employment growth and technology.

**Other studies**

The network developed various studies linking innovation, R&D and various measures of performance, to other economic and institutional conditions. These studies show that the relationships between innovation and productivity can be linked to several factors and characteristics of an economy.

In the Madrid workshop Bond presented a progress report on a joint work with Meghir and Windmeijer on the investment and productivity effects of takeover threats (Bond, Meghir and Windmeijer, 1998). The issue is important because especially in recent years takeovers and takeover threats have influenced various aspects of corporate performance and industry structure. Particularly, it is important to understand whether they reduce the incentives of companies to undertake long-term plans, and hence restrain company growth, investment and productivity. Bond, Meghir and Windmeijer (1998) examined the effects of takeover threats on investment and productivity first in a theoretical model and then in a large empirical study of UK manufacturing firms during 1975-1992. Their preliminary empirical results suggest that the threat of takeover has no effect on productivity, but has a negative effect on investments.

Another interesting set of studies initiated by the researchers in this network focused on the productivity of public research institutions, as well as the effects of public R&D grants or subsidies on private firm R&D investments and productivity. This is an important stream of research. In fact, while economists have developed a great deal of theoretical and empirical work on private R&D, we know very little (both theoretically and empirically) about the productivity of public research institutions (e.g. universities), and about the effects of public R&D grants and subsidies. This is a rather serious shortcoming of economic analysis if we consider that in the advanced economies between 40% to 60% of total R&D expenditures are publicly funded.

The productivity of public research institutions, and particularly of universities, has recently attracted the attention of some economists (e.g. Adams and Griliches, 1998). Within this network, Arora, David and Gambardella (1998) developed a structural model to estimate the production function of scientific publications using a data set on about 800 research groups that applied to a 1989-93 public research programme in biotechnology in Italy. The average elasticity of research output (quality-adjusted publications) with respect to the research budget is estimated to be 0.6; but, for a small fraction of groups led by highly prestigious
scientists this elasticity approaches 1. These estimates imply that a more unequal
distribution of research funds would increase research output in the short-run.

Arora and Gambardella (1998) used data on 1473 applications by US economists
to NSF during 1985-1990, 414 of which were awarded a research grant. They ask
whether the NSF grant was a critical resource for later publications or whether the
NSF grant crowded out other resources and the publications would have been
produced in any case. They found that this effect of NSF funding seems to be
more pronounced at earlier stages of the career of economists.

Klette and Moen (1998) addressed a similar question by looking at the R&D
subsidy schemes to private firms from the Norwegian research councils. They
found that these schemes have been quite effective in stimulating private R&D
investments. At least in the short run there seems to be a significant increase in the
firms’ own R&D expenditures when they receive R&D subsidies. The analysis
also explores the longer run impacts of R&D grants by means of a framework
emphasizing learning-by-doing in R&D activities. They argue that such learning-
by-doing effects can be quite important, and the paper presents a theoretical
analysis showing that such learning effects will give rise to permanent increases in
R&D activity of temporary subsidies. They estimated a structural, econometric
model of R&D investment incorporating such learning effects, with reasonable
results. The Klette-Moen study is also important because, while there are a few
studies on the effects of indirect schemes for R&D support, like tax credit (e.g.
Hall, 1993 and 1995; Bloom, Griffith and Van Reenen, 1997), there are
practically no studies on the effects of direct R&D support schemes, which are
quite common especially outside the anglo-saxon world.

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