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On the Changing Nature of Technological Accumulation and Innovation. From S&T to Industrial R&D

Traditional R&D-based technological progress which is still very much dominant in many industrial sectors ranging from the chemical and pharmaceutical industries to motor vehicles, semiconductors and electronic consumer goods has been characterized by the ability to organise technological improvements along clear agreed-upon criteria and a continuous ability to evaluate progress. At the same time a crucial part of the engineering research consisted, as Richard Nelson put it, "of the ability to hold in place": to replicate at a larger industrial scale and to imitate experiments carried out in the research laboratory environment. As a result it involved first and foremost a cumulative process of technological progress: a continuous learning from natural and deliberate experiments.

Keywords: *innovation, science, technology, research and development*

1. Introduction

Science and Technology has been the subject of public interest and support for centuries. The acceptance of a utilitarian argument for the public support of basic scientifi research predates the Industrial Revolution itself. Although government and university laboratories had existed earlier, it was only in the 1870s hat the first specialised R&D laboratories were established in industry (Mowery, 1983).What became most distinctive about this form of ndustrial R&D was its scale, its scientific content and the extent of its professional specialisation. A much greater part of technological progress became now attributable to R&D work performed in specialised laboratories or pilot plants by full-time qualified staff. It is this sort of professional work, which is today recorded in official, internationally harmonized R&D statistics. Already in the early days of defining what was to become the OECD Frascati Manual definition of "R&D", it was obvious that it would not be possible to measure the part-time and amateur inventive work of typical 19th century research. The present industrial R&D statistics are therefore a reflection, and also a measure of, the professionalisation of R&D activities. And while the extent of secialisation should not be exaggerated – even today in many manufacturing firms the "technical" or "engineering" departments or "OR" sections contribute far more to the technical improvement of an existing process than the formal R&D department, more narrowly defined – the balance has significantly changed over the 20th Century with a gradual further specialisation of the R&D function. It is the emergence of this particular function, which can be most closely identified with the emergence and growth of the industrial society.

This industrial research "revolution" was, however, not just a question of change in scale. It also involved a fundamental change in the relationship between society on the one hand and technology and science on the other. The expression "technology", with its connotation of a more formal and systematic body of learning, only came into general use when the techniques of production reached a stage of complexity where traditional methods no longer sufficed. The older, more primitive arts and crafts technologies continued to exist side by side with th new "technology". But the way in which more scientific techniques would be used in producing, distributing and transporting goods led to a shift in the ordering of industries alongsid their "technology" intensity. Thus, typical for most Western industrial societies of the 20th Century, there were now high-technology intensive industries, having as major sectoral characteristic the heavy, own, sector-internal R&D investments and low-technology intensive, more craft techniques based industries, with very little own R&D efforts. And while in many policy debate, industrial dynamism became as a result somewhat naively associate with jus the dominance in a country's industrial structure of the presence of high-technology intensive sectors, the more sophisticated sectoral studies on the particular features of inter-sectoral technology flows, from Pavitt (1984) to Malerba (2004), brought back to the forefront many of the unmeasured, indirect sources of technical progress in the analysis.

At the same time, the "science" and "technology" parts of research developed increasingly autonomously and with an increasing degree of independence from each other, certainly when compared to the early phases of the Industrial Revolution. The latter could be described as a period of "industrial enlightenment" (Mokyr, 2005): a period of close and fruitful interactions between industrialists searching for a better scientific understanding of their technological inventions, and scientists keen on understanding the underlying scientifi principles of those new ndustrial technologies. Thus the further development of the steam engine influenced thermodynamics, whilst scientific knowledge of electricity and magnetism became the basis for the electrical engineering industry. The two bodies of knowledge were nevertheless generated by distinct professions in quite different ways and with largely independent traditions. The scientific community was concerned with discovery and with the publication of new knowledge in a form, which would meet the professional criteria of their fellow scientists. Application was ultimately of secondary importance or not even considered. For the engineer or technologist on the other hand, publication was of secondary or negligible importance. The first concern was with the practical application and the professional recognition, which came from the demonstration of a working device or design.

Elsewhere I have described the growing dichotomy between science and technology over the last two decades as a "Dutch knowledge disease" phenomenon (Soete, 2004). A process, which has been set in motion in the 1970/80s and consisted of a dual "crowding out". A "crowding out" of fundamental, basic research from private firms' R&D activities on the one hand and a process of "crowding out" of applied research from public, primarily academic university research. The first process found its most explicit expression in the reorganisation of R&D activities, from often autonomou laboratories directly under the responsibility of the Board of Directors in the 60's to more decentralized R&D activities integrated and fully part of separate business units.

Today only firms in the pharmaceutical sector and a couple of large firms outside of this sector are still involve in the funding and carrying out of fundamental research (as reflected e.g. in the number of scientific publications authored by private firms). For most firms the increased complexity of science and technology has meant a greater focus on applied and development research and a more explicit reliance on external, university or other, often public, knowledge centres for more fundamental research input.

Firms now "shop" on the world market for access to basic and fundamental research and choose the best locations to locate their R&D laboratories. In doing so they will not only hope to make their own, in-house R&D more efficient, but also look to the efficiency, quality, and dynamics of the external universities and public R&D institutions.

At the other end of thespectrum, public research investments in universities and other public research institutes became, in most advanced countries, increasingly subject to national public scrutiny ove the 80's and 90's through systematic performance assessment and academic peer review. As a result, academic performance became even more explicitly the dominant incentive in public research institutes while applied, or more immediately relevant research, was second rated. Hence, in many countries, particularly in Europe, applied research became "crowded out" of the university environment.

These opposing "crowding out" trends in the nature o private and public research have to some extent accompanied the gradual shift in the economy from an industrial society to a more service based, immaterial economy, in which industrial production is no longer the prime recipient and carrier of technological improvement.

2. The emerging knowledge economy paradigm

There has been over the last twenty years a major shift in the understanding of the relationships between research, innovation and socio-economic development.

First, economists have come to accept that knowledge accumulation might well be analysed, like the accumulation of any other capital good.

In short that economic principles can be applied to the production and exchange of knowledge; and, that knowledge is intrinsically endogenous to the economic and the social system, not an external, "black box factor only to be opened by scientists and engineers" in Christopher Freeman's (1974) celebrated words. Hence, while knowledge has some specific features of its own, it can be produced and used in the production of other goods, even in the production of itself, like any othercapital good that is used a an input in the production process. It also can be stored and will be subject to depreciation, when skills deteriorate or people no longer use particular knowledge and, in the extreme case, forget about it. It might even become obsolete, when new knowledge supersedes and renders it worthless; as in the case with leading-edge technologies.

However, there are some fundamental differences with traditional industrial capital goods. First, and foremost, the production of knowledge will not take the form of a physical piece of equipment, but will be embedded in some specific blueprint form (a patent, an artefact, a design, a software program, a manuscript, a omposition), in human beings or even in organisations. In each of these cases there will be so-called positive externalities: the knowledge embodied in such blueprints, people or organisations cannot be fully appropriated, it will with little cost to the knowledge creator flow away to other firms or to the public knowledge stock. Knowledge is from this perspective a non-rival good. Many people can share it without diminishing in any way the amount available of any one of them.

Second, the emergence of the cluster of new information and communication technologies (ICTs) has also had a direct impact on research, international knowledge access and innovation. ICTs are in the real sense of the word an information technology, the essence of which consists of the increased memorisation and storage, speed, manipulation and interpretation of data and information. In short, it is what has been characterized as the codificatio of knowledge. As a consequence, information technologymakes codified knowledge, data and information much more accessible than before it all sectors and agents in the economy linked to information networks or with the knowledge how to access such networks. But ICTs have also had a direct impact on the R&D process itself.

Research laboratories are today equipped with sophisticated ICT equipment allowing more precision, reliability and expanding dramatically the scope for research in many different scientific fields. The intensive use of sophisticated ICT instruments in the process of R&D is one of the major factors contributing to the increase in the efficiency in research over the last decades.

At the same time, the increased potential for international codification and transferability of knowledge linked to the use of ICTs, implies that knowledge, including economic knowledge becomes to some extent globally available. While the local capacities to use or have the competence to access such knowledge wil vary widely, the access potential is there. ICT, in other words, brings to the forefront the enormou potential for catching-up, based upon cost advantages and economic transparency of (dis-) advantages, while stressing at the same time the crucial tacit and other competence elements in the capacity to acces international codified knowledge. For technologically leading countries or firms, this implies increasing erosion of monopoly rents associated with innovation and shortening of product life cycles. Research efforts maynot be profitable anymore in this setting, from the perspective of a single firm. The ability of each economic actor to innovate single-handedly in such a global setting is becoming more risky, and stresses the role of strong technology clusters and government investment in knowledge.

Third, the perception of the nature of innovation processes has changed significantly over the last decade. Broadly speaking, innovation capability is seen less in terms of the ability to discover new technological principles, but more in terms of the ability to exploit systematically the effects produced by new combinations and use of pieces in the existing stock of knowledge (David and Foray, 2002). This new model, closely associated with the emergence of numerous knowledge "service" activities, implies to some extent more routine use of a technological base allowing forinnovation without the need for leaps in technology, sometimes referred to as "innovation without research". It requires systematic access to the state-of-the-art technologies; each industry must introduce procedures for the dissemination of information regarding the stock of technologies available, so that individual innovators can draw upon the work of other innovators. This mode of knowledge generation--based on the recombination and re-use of known practice--raises also much more information-search problems and must confront the problems of the impediments to accessing the existing stock of information that are created by intellectual property right laws.

The new concept of a "science, technology and innovation system" is, in other words, shifting towards a more complex, socially distributed structure of knowledge production activities, involving a much greater diversity of organizations having as explicit goal knowledge production. The old system reviewed above under a), was, by contrast, based on a simple dichotomy between knowledge generation and deliberate learning (R&D laboratories and universities) and activities o production and consumption where the motivation for acting was not to acquire new knowledge but rather to produce or use effective outputs. The collapse (or partial collapse) of this dichotomy leads to a proliferation of new places having the explicit goal of producing knowledge and undertaking deliberate research activities, which may not be readily observable but nevertheless essential to sustain innovative activities in a global environment.

To summarize, traditional R&D-based technological progress which is still very much dominant in many industrial sectors ranging from the chemical and pharmaceutical industries to motor vehicles, semiconductors and electronic consumer goods has been characterized by the ability to organise technological improvements along clear agreed-upon criteria and a continuous ability to evaluate progress. At he same time a crucial part of the engineering research consisted, as Richard Nelson put it, "of the ability to hold in place": to replicate at a larger industrial scale and to imitate experiments carried out in the research laboratory environment. As a result it involved first and foremost a cumulative process of technological progress: a continuous learning from natural and deliberate experiments.

The more recent mode of technological progress described above and more associated with the knowledge paradigm and the service economy, with as extreme form the attempts at ICT-based efficiency improvements in e.g. the financial and insurance sectors, the wholesale and retail sectors, health, education, government services, business management and administration, is much more based on flexibility and confronted with intrinsic difficulties in replication. Learning from previous experiences or from other sectorsis difficult and sometimes even misleading. Evaluation is difficult because of changing external environments: over time, among sectors, across locations. It willoften be impossible to separate out specifi context variables from real causes and effects. Technological progress will in other words be much more of the trial and error base yet without as in the life sciences providing "hard" data, which can be scientifically analysed and interpreted. The resultis that technological progress will be less predictable, more uncertain and ultimately more closely associated with entrepreneurial risk taking. Attempts at reducing such risks might involve, as Von Hippel (2004) has argued, a much greater importance given to users, already in the research process itself.

This shift as I will argue in the next section has major implications for the functioning of the ESM, as typified in the German version of that model.

The German social model was to some extent the "ideal" type of social industrial model (with Japan) with strong incentives for firms to invest in the internal learning and upgrading of their work force, a close and privileged interaction between firms and higher education establishments (dual learning systems) and specialized industrial R&D and engineering departments, guaranteeing a continuous improvement in production and organisational efficiency. It resulted in continuous improvements in the international competitiveness (unit labour costs) of German production as reflected in German trade surpluses, still the case today. It also explains the high expectations of economists in the 80's of the German (and Japanese) "*Standort*" likely to take over US industrial technology dominance.

Compared to the new mode of technological progress, the previous advantages of this social model are now quickly turning into disadvantages primarily associated with major emerging inflexibilities, which are to some extent at loggerheads with the newly required flexibility in the new knowledge paradigm.

3. Reflecting on the implications for Europe's social model

The organisational and social challenges associated with the emerging new knowledge paradigm described above and also closely associated with the service economy and the "e-conomy", have, and maybe somewhat paradoxically given the original emphasis on e-Europe in Lisbon, not really been addressed in the discussions leading up to the Lisbon summit. Most of the discussions focused on the technological aspects of knowledge creation and development, the lagging position of the EU vis-ŕ-vis the US, the need for a European research area and better coordination of member states research policies, the shortages of scientists and engineers, etc. The challenges of the emerging knowledge paradigm for the social models in European members states (MS) were barely addressed.

Yet it is clear that in a knowledge-driven society as described above there are likely to be many institutional, social and cultural bottlenecks to entrepreneurial risk taking, trial and error innovation and the ensuing creative destruction, which touch directly on the functioning of the ESM. To some extent the Lisbon declaration was not only an expression of a political desire to strive for a Europe belonging to the world's most knowledge-intensive regions in ten years, but also that this was to happen within the context of a strengthened, 'activated' social Europe that would have an eye for past social achievements.

The question that was *not* addressed was how activating labour markets would enhance the shift towards the new knowledge paradigm.

Economists such as Giles Saint-Paul have analysed the relationship between labour market institutions, and in particular the costs of hiring and dismissing employees, and the development of innovations from a purely theoretical perspective. Hiring and firing costs are in many ways the most explicit manifestation of the industrial employment "security" embedded in European continental social welfare states – the Bismarck model. They have led to stability in labour relations and have represented a useful incentive for employers and employees alike to invest in human capital. However, in terms of the new knowledge paradigm and in particular the accompanying process of "creative destruction" which might accompany the development of new activities – whether concerned with new product, process or organisational innovations – this model will raise dramatically the costswith which "destruction" can be realized. Thus as shown in Saint-Paul's model, the US, with lower firing costs, will eventually gain a competitive advantage in the introduction of new, innovative products and process developments onto the market, while continental Europe will become specialized in technology-following activities, based on secondary, less radical improvement innovations.

In other words, the dynamics of innovation, of entrepreneurship, of creative destruction thrives better in an environment providing higher rewards for creativity and curiosity than in an environment putting a higher premium on the security of employment, internal learning and efficiency improvements in the production of existing products. Viewed from this perspective, the gap between Europe, and in particular continental Europe, and the United States in terms of innovative capacity, efficiency, and wealth creation may look like the price Europe had to pay for not wanting to give up the social securities and achievements associated with its social model. Many of the proposals on "activating the labour market" with by now popular concepts like "empowerment" and "employability" appear to go hand in hand with innovation and growth dynamics, others though do not. Some European countries such as the UK and Denmark appear to have been more successful in reducing dismissing costs than others, and appea to have benefited much more from the knowledge paradigm in terms of growth dynamics.

The central question, which must be raised within this context is whether the social security model developed at the time of the industrial society is not increasingly inappropriate for the large majority of what could be described as "knowledge workers": workers who are likely to be less physically (but by contrast possibly more mentally) worn out by work than the old type of blue collar, industrial workers. The short working hours, the early retirement schemes, the longer holidays might well appear to knowledge workers less of a social achievement; work not really representing a "disutility" but more an essential motivating activity, providing even a meaning to life.

There is in other words, I would argue a need for a fundamental rethinking of the universality of social security systems in European countries social welfare systems. That rethinking should recognize explicitly the emerging duality in the labour force betwee work involving "*labour*", i.e. a physical or mental wearing out activity, and work involving "*pleasure*", i.e. activities providing primarily self-satisfaction in terms of recognition, realisation and creativity. Workers involved in the first sort of activity will consider the social achievements, including employment security, a relatively short working life and short weekly working hours, as important social achievements and intrinsically associated with their quality of life, which they will not be prepared to give up.

Workers involved in the second sort of activity, have been given hese similar social rights by extensio because of labour law universality principles. At the same time such an automatic extension of social rights appear by and large inappropriate and could be considered to be behind the lack of dynamism of knowledge workers in Europe. Furthermore, the full application of the social model to the growing proportion of knowledge workers undermines the sustainability of the social model itself. In short, when work involves significant positive externalities as in the case of knowledge work, it appears particularly inappropriate to apply social "security" guarantee to employment aimed first and foremost at reducing the negative externalities of physical work.

4. Conclusions

The new Lisbon strategy "Integrated Guidelines for Growth and Jobs" consists of 24 guidelines brought together under five broad headlines.Reflecting the reformulation of the political priorities of the Lisbon strategy after the mid term review (July 2005) under three headlines ("knowledge and innovation – engines of sustainable growth"; "making Europe a more attractive place to invest and to work"; "more and better jobs") the different guidelines appear, I would argue, still poorly integrated. In this paper the focus has been on the first of these political priorities: knowledge and innovation. Europe's failure to achieve significant progress under this heading over the last five years has much to do with the interaction between knowledge and innovation and the three other broad guidelines considered in Table 1. The knowledge society which has emerged in Europe is, as has been argued here, indeed not an exogenous one, external to Europe's macroeconomic policy, competition policy or social model, but fully endogenous to those other areas of economic policy.

In this sense our discussion, while limited to the social policy implications of the shift from industrial R& to information based innovation, highlights nevertheless the complete lack of integratio of the knowledge and innovation Lisbon priority with the other areas of the Lisbon strategy. The Lisbon strategy interpretation of "knowledge and innovation as engines of sustainable growth" represents still, I would argue, and despit brave attempts of the Commission to proof the contrary, a very segmented policy approach, addressing first and foremost the traditional R&D and innovation member countries and EC policy constituencies.

The proposed guidelines and the further detailed proposals from the Commission (EC, 2005) are from this perspective more reminiscent of the old industrial R&D model than of the emerging knowledge economy paradigm model described above. The only shift in attention paid is with respect to potential regulatory barriers to research and innovation, reflecting the broadening ofvision no longer to limit support policies to just R&D but also to include now more systematically innovation, raising at the same time new competition policy issues. However, no attention is paid to interactions with Europe's social model, or with education policy buried as guideline 23 under the "more and better jobs". The result of this relatively narrow focus is that the proposed integrated guidelines are anything but integrated and convey an impression of "over-structure" with target setting on a multitude of particular aspects of knowledge and innovation which are by and large outside of the control of policy makers.

Second, there is, I would argue a need for a fundamental rethinking of the universality principles of social security systems as they were developed in Europe last Century, in a variety of ways, in broad synergy with the emerging industrial society. Such a rethinking should recognize the duality in the labour force between work involving "*labour*", i.e. a physical or mental wearing out activity, and work involving "*pleasure*", i.e. activities providing primarily self-satisfaction in terms of recognition, realisation and creativity. As I argued in section 2 of this paper, workers involved in the first sort of activity are likely to consider the past social achievements of the European social model as important achievements intrinsically associated with their quality of life. They will consider any change of those conditions as a clear deterioration in their quality of life and reject it. Workers involved in the second sort of activity, call them knowledge workers, are not so much in need of social measures aimed at reducing negative externalities of physical work. Their work involves primarily positive externalities. Obviously they also will appreciate social "security" guarantees their employment, but these will rather be used as substitute rather than as complement for own life long learning efforts and investments. Effectively, knowledge workers are "free riding" on social "security" guarantees designed in another industrial age and aimed at a different category of workers. The automatic extension of social rights to knowledge workers appears from this perspective not only unjustified, undermining the financial sustainability of the European social model, but could well also explain the lack of dynamism of knowledge workers in Europe.

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