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The Framework Programmes and the Changing Economic Landscape

Keith Smith

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This paper discusses some changes in the economic 'landscape', including institutions, infrastructures, regulations and economic processes, within which European RTD policy is formed and implemented. It is part of the "knowledge-base" underpinning the Five-Year Assessment of the European Union Research Framework Programmes 1999-2003, which was carried out by a high level independent expert panel in the second semester of 2004.

This publicly available collection of nearly 150 documents includes 22 Community assessments or evaluations, 7 evaluation policy and methodology documents and 12 national impact assessments or evaluations. It also contains 69 policy documents and reviews and reference documents such as previous monitoring or Five-Year Assessments, Annual reports on research activities (art. 173), indicators and the Framework Programmes' legal base.

These documents are available on
http://forum.europa.eu.int/Public/irc/rtd/fiveyearasskb/library.

THE FRAMEWORK PROGRAMMES AND THE CHANGING ECONOMIC LANDSCAPE

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Summary

This paper discusses some changes in the economic 'landscape' within which European RTD policy is formed and implemented. The landscape is interpreted as the complex of institutions, infrastructures, regulations, and economic processes within which technological artefacts are developed and put to use. Four main dimensions of the changing landscape are discussed: the economic reform agenda which has dominated policymaking in recent years, current macroeconomic imbalances in the world economy, changing policy concepts in RTD policy, and problems of environmental sustainability. The paper argues that the reform agenda has transformed the infrastructural conditions underlying technological change, in ways that require attention from policymakers. It suggests that policy-driven changes in the governance of universities are likely to lead to significant changes in university-industry interactions. It suggests that globalisation does not remove either the need or the possibility for governments to act in support of R&D and innovation processes; on the contrary it intensifies such needs. It suggests that changing concepts of and approaches to R&D and innovation necessitate shifts in policy approaches and instruments. Finally it argues that environmental issues are now so serious that they will require large mission-oriented programmes to find alternatives to the hydrocarbon technologies that dominate our current technological systems.

1. Introduction[1]

Science and technology policies are often analysed on the basis of economic models that assume a static economic background. This is particularly the case with mainstream economic approaches that address policy issues by identifying market imperfections, with a relative neglect of institutions and institutional change. More heterodox approaches, especially in evolutionary economics or 'systems' theories of innovation, stress technological dynamics and the institutional background as an essential framework for economic behaviour. However they also often treat the institutional structure as unchanging. So these approaches share a relative lack of attention to such things as changes in the rules and regulations governing economic behaviour, or changes in business procedures. In terms of technological change, even the approaches associated with Schumpeterian or evolutionary economics often place limits on their analysis of how technological change reshapes or is reshaped by the economic environment. This is mainly because some influential approaches see institutional change as an effect of the technological environment, rather than as something shaping it. Policymakers tend to be more inclined than economists to take economic and institutional change into account, but they often understand change in limited ways – especially in terms of the allegedly major impacts of 'critical technologies', such as ICT, biotechnology or nanotechnology.

In practice, market economies are far from static. They are instead characterized by continuous change, and sometimes considerable turbulence, and this often limits the potential of mainstream economic approaches. At the same time, such change cannot be reduced to the effects of major technological revolutions – on the contrary, institutional change in particular is rather autonomous, and can have important effects on the RTD and innovation systems. To what extent should policymakers in science and technology take account of such change? This paper looks at change in the economic 'landscape', exploring their implications for the design and implementation of programmes such as Framework.

This paper uses the term 'landscape' to refer to the complex of institutions, infrastructures, regulations, and economic processes within which technological artifacts are developed and put to use. This is a concept of landscape which is quite close to one sometimes used in innovation studies to distinguish between different levels at which technology can be considered; its most systematic use is by Arie Rip and Rene Kemp.[2] The economic landscape within which the Framework Programmes operate can be approached from a number of directions. The perspective here is to focus on the

[1] Please note that this paper represents the analyses and views of the author only, and not those of IPTS. The author would like, however, to thank IPTS for the opportunity to work on this paper.

[2] Rip, A. and Kemp, R. (1998), 'Technological Change', in: S. Rayner and Malone, E.L. (eds), *Human Choice and Climate Change*, Columbus, Ohio: Battelle Press. Volume 2, 327-399.

dynamics of three main dimensions of the economic/technological environment. These are:

- The changing economic environment – economic reform processes, changes in economic structure and organisation, and globalisation and closer economic integration
- Macroeconomic conditions and their policy challenges concepts and understanding of science, technology and innovation
- The increasing technological problem of environmental sustainability

2. The changing economic environment

The past two decades have seen major changes in the structure of economic organisation. Many of these changes have implications that remain unclear, or that have yet to be incorporated into the thinking behind RTD policies. This section discusses, with varying length and detail, the broad process of economic reform, and then some of its components.

2.1 The economic reform agenda and process

Since the mid-1970s, the main thrust of economic policy in OECD economies has been towards economic liberalisation and a generally more market-oriented approach to policy issues. In recent years the basic economic policy focus both at national and European levels has been on macro- and micro-economic reform: trade liberalisation, deregulation of financial markets, privatisation, and labor market reform. This has been accompanied by attempts to reduce public expenditure as a proportion of GDP, and by shifts in the provision of public services towards more market-oriented approaches. This broad policy has had two aims. The first is cost-reducing efficiency improvements that enhance productivity; the second is the creation of an economic environment that promotes sustained economic growth.

In its more explicit formulations, such as the so-called Washington Consensus driving the operations of the World Bank and the IMF, the reform shift is often seen as an Anglo-American formulation deriving from the Reagan-Thatcher administrations. However neo-liberal ideas have been very influential across Europe, leading to diverse reform processes across every European economy. These processes cannot simply be reduced to working out of an Anglo-American model, in particular because European reform processes continue to rest on different conceptions of the role of the state, and different views about the responsibilities of government. Liberalisation measures in France, the Netherlands and the Nordic region, for example, have been very far reaching (and often have a rather long political history – Swedish telecoms deregulation

began in the 1960s, for example). These liberalisation measures often rest on very different political conceptions from those of the Washington Consensus. Europe also has a specific dimension of reform for which the Washington Consensus has shown itself to be a poor guide, namely the reform and reconstruction of the former socialist countries, and the reform issues faced by countries newly acceding to the EU. Against this background there seem to be at least four dimensions of economic reform that are significant in thinking about the changed landscape of FRAMEWORK.

These are

- Industry deregulation and privatisation programmes
- Globalisation: liberalisation of financial markets, closer global integration of money and capital markets, and changes in corporate governance processes; and the integration of trade issues with technological matters (such as the TRIPS agreement at the WTO)
- Changes in the governance of universities
- Institutional reconstruction in the accession countries

With the exception of the last item on the list above, it is important to note that many of these changes were driven by discretionary policy decisions that were not the result of inexorable economic forces, or of technological imperatives. In general, they were worked out via domestic decisions or inter-government agreements that could readily have taken different forms. In terms of economic imperatives, of course governments usually had potential economic benefits in mind, often related to overcoming the productivity slowdown. But these objectives did not compel the particular reform solutions that were chosen. From the technological side, it is sometimes argued that such technological developments as the integration of computing and telecommunications fostered financial integration. But it is probably more appropriate to see the causality the other way around – that integration decisions drove the development of communications systems, integrated trading platforms, etc.

Taken together, these reform processes have resulted in major changes in the economic environment. Following sections briefly discuss the character of change in each of these areas, finishing with a discussion of the relation between reform and growth. Each section sketches some of the RTD policy implications as they affect the FRAMEWORK programmes.

2.2. Industry deregulation and privatisation

Within the reform agenda, industrial policy has aimed at privatisation and deregulation, with governments focusing on framework issues and in the main withdrawing from direct interventions. A key issue for RTD policy is how does this changed policy focus accords with the increasing innovation intensity of modern business. The period of

policy liberalisation has also seen major scientific and technological revolutions which continue to have profound impacts on business organisation and strategy, accompanied by the extension of innovation-based competition to a global scale. Across all sectors – not just those directly producing advanced science-technology products - innovation and learning are central to enterprise survival and growth. How are innovation processes affected by liberalizing economic policies?

At the level of firms, the most significant effects of reform on capabilities come via privatisation of publicly-owned enterprises, or wider processes of industry deregulation. Although privatisation has not always reduced the exploitation of dominant positions (arising from, for example, the control of fixed line networks in telecommunications) it has been associated with greater flexibility, often sharp increases in labour productivity, and willingness to innovate.

However behind this there is a wider problem which may deserve consideration in the context of the FRAMEWORK programmes. This concerns the nature of knowledge infrastructures, and their wider social and economic effects. Under public ownership, utilities in such fields as energy and telecoms had major technology development capabilities, often maintaining significant research labs and long-term RTD programmes aimed at innovations that could be extremely radical. The most notable case of this in Europe has been modern mobile telecommunications, which emerged in large part from a fifty-year development effort conducted by Nordic state telecoms agencies and their research labs. These agencies developed the basic architectures, network technologies, handset systems, and standards that led to GSM and subsequent te4lecoms systems. This effort has a major impact in placing Europe as a whole in a strong position in this field. Privatisation has affected such capabilities across a range of privatized large firms, with generally falling R&D intensities, and a greater focus on innovation related to current lines of business.

The old system of state-owned firms and their research labs could be seen as a kind of knowledge infrastructure, which managed such system-wide innovations as telecom digitalisation. The issue for the FRAMEWORK programmes is whether this infrastructure issue matters. Within FRAMEWORK there is an infrastructure component, but this is conceptualized mainly in terms of large science facilities. There is an issue of whether the infrastructure concept should be widened, perhaps towards long-term technology platforms and their associated organisations, but certainly considering the nature, coherence and governance of RTD infrastructures as a component of the European RTD effort. Privatisation and deregulation have been a major change in the RTD landscape – they have brought many economic benefits, but there are also potential costs, in terms of long-term technology capabilities, which ought to be reconsidered in the context of the infrastructural tasks of FRAMEWORK.

2.3 Changes in the governance of universities

Universities in Europe present an especially complicated mix of institutional and organisational forms, so it is dangerous to generalize about them. However throughout Europe there have been attempts to reform university governance, usually in the direction of making universities in some sense more responsive to economic or industrial needs. In at least one European country the entire functioning of the university system has been officially redefined in terms of support for the economic system. Specific measures have included a strong emphasis on industrial collaboration, and industrial funding for research, along with a strong emphasis on commercialisation of university research, patenting by universities, and the creation of spin-off companies. What is unclear is how these measures and trends affect the long term research capabilities and profiles of universities, especially in terms of basic research in fields that might potentially have commercial outcomes. The relation between the4 governance changes and university science capabilities is clearly important for FRAMEWORK, for several reasons. These derive simply from the fact that universities are major players in the FRAMEWORK programmes, and there capabilities will shape future possibilities with respect to specific research areas, as well as the development of technology platforms.

2.4 Globalisation and economic integration

Globalisation, in the form of (a) increasing interdependence of economic activities, and (b) increasing global mobility of economic activities and processes, is a key change in the environment over the past two decades. There is a wide range of relevant indicators and processes: the most notable are increasing foreign direct investment (FDI), and growth of global supply chains in manufacturing. With respect to RTD there has been increasing mobility of students and researchers, increasing international collaboration in science and technology, and increases in the international flow and use of science and technology, as indicated by increasing FDI, and increasing technology balance of payments flows. While Europe participates in most of these processes there is a sharp disparity between the US and the EU with respect to inflows of highly skilled workers: in 1999 the US had an inflow of 370,000 highly skilled workers as opposed to 5,300 for France, 8,600 for Germany and 39,100 for the UK.[3]

Most of these indicators – and FDI in particular – are growing globally at rates that far outstrip the growth of GDP. These trends are pronounced within Europe. For all EU economies, the share of R&D performed by foreign affiliates is large and growing. For such economies as Italy, Spain, the UK and Austria, nearly half of all patents are produced by foreign affiliates. At the same time, for most EU economies, between 20 and 50 percent of national patents are produced abroad.

[3] OECD, "International Mobility of the Highly Skilled", *Policy Brief*, July 2002.

The issues raised by this process are complex. At least three major problems might be identified.

First, the deregulation of capital markets has not just promoted FDI, it has also led to very substantial portfolio shifts, often led by large pension funds or mutual funds. It is common for European stock markets to have very substantial percentages of shares held by non-nationals. On the one hand this introduces issues concerning the effects of these shifts on corporate governance, but on the other it raises wide questions about the implications of ownership for national policies. At the most basic level, there are questions concerning the feasibility of national or European RTD policies at all, in the sense of policies that are aimed at benefiting the citizens or enterprises of a particular state or region. The benefits of successful company- or sector-oriented RTD policies are likely to spread well beyond the particular taxpayers who financed them.

Second, what is the appropriate scope of international policy collaboration? An obvious response to this situation is to expand the coherence and integration of RTD across borders, and this is a central objective of the European Research Area (ERA) initiative. As European economic integration proceeds, the arguments behind ERA become very strong. But the impacts of globalisation go much further, and so this suggests a need for wider approaches to international collaboration both in ERA and the FRAMEWORK programmes.

Thirdly, there is the issue of localisation. In this increasingly fluid environment, RTD performance of a country or region may depend significantly on localisation decisions by firms. Localisation decisions, and the factors that affect them, thus become an important issue for RTD policymakers.

Again, this is a complex area that can be approached from multiple angles. However it might be argued that globalisation does not diminish the importance of the national innovation system (NIS). On the contrary, it enhances the importance of the NIS since the NIS provides location-specific assets that either create incentives for localisation, or enhance the productivity and production complexity of other geographically specific assets. It should be remembered that when people discuss national innovation systems they are usually referring to a core framework consisting of the education and training system, health and welfare policies, the RTD infrastructure, and the finance system for innovation. These are areas that are not particularly affected by globalisation and are under strong domestic policy control. A good example of this can be found in the pharmaceuticals sector. The key location for pharmaceuticals R&D has become the USA, and all major European players have established labs in the USA. The locational attractiveness of the USA is largely driven by major infrastructural investment in universities, financed by the National Institutes of Health. The EU has a major pharmaceuticals sector, but nothing to match the basic R&D effort of the NIH, and this has some impact on the location issues. If infrastructural investment is a main

instrument for the creation of location-specific assets, then the key policy problems are deciding which assets are strategically important, for which business fields, and how policies can be shaped to create them. A reasonably coherent economic and business development strategy is needed to make these choices, and co-ordination instruments are necessary to implement them. In Europe this issue is complicated by the interaction of national and European-levels for S&T strategies, an issue which will presumably be a core part of the ERA initiative.

These locational factors are also important in another context. Many European countries are small open economies that are net importers of technology. Accessing, adapting and deploying foreign technologies are central to productivity growth. This means that policies for the NIS must be formed within a clear understanding of the channels of international technology transfer, and of policies and instruments relevant to them.

It is important to distinguish between policies that are affected by globalisation (such as WTO rules with respect to the TRIPS, TRIMS and GATS agreement), and policies that are unaffected. With respect to the WTO, perhaps the most important initiative has been TRIPS. Within the TRIPS Agreement, most attention has focused on the modifications to patent law and practice, but TRIPS is an exceptionally comprehensive agreement, and there are many other articles that have the potential to shape technology policy measures. These include copyright, IPRs for trademarks and geographical indications, registration of industrial designs, integrated circuit layouts, and protection of trade secrets. It is important to be clear about where the rules of the international economy are important for S&T policy makers and what negotiation stances are important – these included policies in such areas as market access, phyto-sanitary standards, geographical indications etc. At the same time, it remains the case that many NIS policies remain firmly under national control, and it is these areas that need focus.

2.5 Institutional reconstruction in the accession countries

Countries that have recently acceded to the EU face major challenges with respect to science and technology institutions. Over the past decade most of the policy attention in these countries has been directed towards such issues as deregulation, the shift from state control to private enterprise, and processes of macroeconomic adaptation (the creation of macro policy institutions, combined with financial reconstruction and open-economy trade and banking institutions). Of course within the accession countries attention has been paid to science and technology issues, but this has been considerably less than that paid to the wider institutions of the market system.

The process of institution building for the science and technology system is now high on the agenda, and it relates to a number of the issues discussed here. First is the question of infrastructure building, which requires decision-making on types, priorities,

functions and dimensions of infrastructure provision. Second, there are important decisions to be made about priorities for RTD support policies. This is an issue discussed in a later section of this paper, namely the question of what sectors or activities might form the focus of RTD support policies. The issue here is to what extent policymakers should seek to create new activities, and to what extent seek to technologically upgrade existing industries. Finally, as innovation systems are reconstructed, there is the problem of how they integrate with those of other EU countries – in other words, how the dynamics of the accession countries will fit into ERA.

3. Assessing the economic reform agenda and its outcomes

What are the overall implications for science and technology policy of the reform agenda described above? It is certainly too early for any serious evaluation of the effects of reform, although some studies of reform processes that argue a strong link between reform and subsequent growth in output and productivity, while other evaluations are frequently sceptical concerning the empirical benefits. For Europe, growth performance in recent years has been mixed. However it would be wrong to draw the immediate conclusion that reform has changed Europe's long-run growth potential, for two reasons. The first is growth may have determinants other than those of the changed policy environment. The second is that recent policy change may have effects on the allocation efficiency of the economy, but not necessarily on its growth potential, which has a wider set of determinants.

In terms of the basic rationale for S&T policy, it can be argued that liberalizing economic policies do not in themselves adequately support innovation capabilities. Certainly many aspects of economic reform contribute to innovation and to improved product or service quality. These include freer entry conditions to formerly regulated industries, improved access to finance, wider markets through trade liberalisation, and generally greater flexibility. However there remain important innovation-relevant functions which markets perform poorly or not at all. These include the provision of finance in highly risky environments, and the creation and distribution of knowledge. The key issue for S&T policy is the creation and use of knowledge across firms and industries, and the role of government in supporting it. It may be that S&T policy requires reform that is different in character from that of the recent reform agenda. This in turn depends on our understanding of the nature of innovation, the processes of learning and knowledge creation that support it, and the role of government in supporting such learning.

The question of how economic reform affects long-run growth is difficult to answer. From a theoretical perspective, economics give little clear guidance as to how moves towards allocative efficiency improve long-term growth potential. Certainly such moves

produce short term output gains as resources move into more productive uses, and as costs decline. In particular, for countries which import most of their capital goods, and which generally are technology importers, trade liberalisation can have impacts on the prices and availability of capital and intermediate inputs, and the technologies that they embody.

But in the longer run growth performance depends on a complex array of factors that may or may not be affected by the macro reform process, but that are rarely fully considered in assessing the likely outcomes of reform. Essentially these factors are the institutions and organisations that affect the creation, maintenance, distribution and use of knowledge in the economic system. These include firm-level innovation capabilities, but also universities, research institutes, regulatory agencies, standards-setting organisations, and intellectual property systems.

University administration and finance, the research institute systems, and the IPR framework have all changed: for universities and the research system, the emphasis has been on expanding industry funding, increasing industry links and direct business pay-offs. Some of these reforms are driven by internal policy changes, while others stem from international initiatives (such as the intellectual property agreements within the WTO). There remains an open question as to how these elements of reform processes so far have affected the knowledge creation capabilities of the system.

The important question for long-term growth performance is how the reform processes related to efficiency and knowledge interact. This is a wide question, but one approach to it is via a consideration of the characteristics of innovation processes in a complex economy. This will be addressed below.

4. Macroeconomic conditions and their policy challenges

At the present time the major economies have some important macroeconomic problems that have implications for growth. In Europe, the "big four" economies of the Eurozone (France, Germany, Italy and Spain) all continue to exhibit high levels of unemployment, and relatively slow growth. Attempts in some countries to relax monetary policy to alleviate unemployment have run into inflation constraints. The arrangements of the Growth and Stability Pact concerning allowable deficits and borrowing constraints are under extreme stress, with little clear direction for European macroeconomic policy at the present time. In the USA, the ability to run major budget deficits combined with very large current account balance of payments deficits (more than 5% of GDP) have meant high short term growth rates.

These issues have at least two significant implications for FRAMEWORK. On the one hand there is the question of assessing relative economic and technological performance, in particular the performance of the EU with respect to the USA. Particularly during the late 1990s the USA experienced strong rates of growth of output and productivity, while Europe performed poorly in aggregate. With some changes, these trends have continued in recent years. Particularly in the late 90s, it was often argued that the growth differentials reflected a science and technology failure on the part of the EU, and in particular a failure to develop and diffuse high-technology based industries. Among those who made these arguments, the macroeconomic determinants of short-run growth were entirely neglected. For example, the ability of the USA to sustain trade deficits (because of the reserve currency status of the dollar) and the major increase in consumption expenditure (and concomitant collapse of savings) were more or less ignored. But with changing macroeconomic conditions we might expect changed growth performance in Europe that could prompt a more realistic assessment of Europe's science and technology performance.

A second issue is that future S&T policy is likely to be conducted in a potentially unstable global macroeconomic environment. But the twin deficits of the US economy are unsustainable, and so an unpredictable adjustment process lies ahead. The centrepiece of the process is likely to be further dollar depreciation, which will have impacts on European exports, and possibly on FDI flows.

5. Concepts and trends in science, technology and innovation

A significant research programme over the past two decades has enhanced our knowledge of innovation processes. This has now generated a series of rather robust results that, taken together, constitute a new understanding of the economics of innovation. However although the results described below can reasonably be describe d as a consensus among academic researchers, they are still far from integrated into policy-making. This is a challenge for FRAMEWORK, not least because most of the relevant research has been carried out in Europe, and has indeed been sponsored by such programmes as TSER and IHP, within FRAMEWORKs 5 and 6.[4]

A central theme in modern innovation research is rejection of the idea that innovation simply flows from some earlier process of scientific or technological discovery – the so-called 'linear model' of innovation. The key element of linear approaches was that technological change was seen as a *sequence of stages*, with new knowledge (usually founded in scientific research) leading to processes of invention, followed by

[4] For an overview of this research, see Jan Fagerberg, David Mowery and Richard Nelson (eds) *Oxford Handbook of Innovation* (Oxford:OUP) 2004

engineering development resulting in innovation (or the commercial introduction of new products and processes). Underlying this was a technocratic view of innovation as a purely technical act: the production of a new technical device. In this framework, technology development and engineering were usually seen as forms of applied science. The linear view of innovation had two basic forms: a 'basic science' model of innovation, and a 'firm-level linear model'.

As the label suggests the core of the 'basic science' model was that innovation sprang from discoveries in basic science, and that basic science provided a flow of results that were then transformed by firms into industrial innovations. At the firm level, the main approach derives from the work of Joseph Schumpeter. He characterized innovation via three processes, namely *invention* (the discovery of a new technical principle and demonstration of its feasibility), *innovation* (the first development of the invention in its commercial form), and *diffusion* (the process of adoption by users). These are seen as distinct phases of innovation, and in this Schumpeter was followed by the analytical literature for many years.

Recent analysis has stressed the interactive character of innovation, both within the firm and external to it. Recent research sees innovation

- first, as an interactive social process which integrates market opportunities with the design, development, financial and engineering capabilities of enterprises,
- second, as a process characterised by continuous feedbacks between the above activities, rather than by linear transitions,
- third, as a process characterised by complex interactions between enterprises and their external environments
- fourth, as a process which is cumulative, a process over time, in the sense that it depends in part on past achievements and the experience derived from them, but also on the ability to modify and develop qualitatively on the basis of the past.

The key robust results of recent innovation research include the following:

Innovation outcomes rest on complexity and variety in investment patterns that transform the capabilities of enterprises. Firms face the challenge of investing in the creation of capabilities, and this happens in a wide variety of ways that cannot be reduced to one or even a few models. This variety and diversity provides major challenges to S&T policy makers.

Innovation is pervasive. Innovation is not something that happens only in a relatively small group of high-technology industries, nor something that is driven by a small set of industries or technologies. The new innovation data, particularly from the EU, show clearly that innovation in the sense of development and sales of new products is distributed right across the system in all advanced countries. Industries that are

regarded as 'traditional' or mature or 'low-tech' often generate substantial amounts of sales from technologically new products and processes.

Innovation relies on collaboration and interactive learning. Enterprises very rarely innovate without technological cooperation or collaboration. Knowledge creation happens through an interactive process with other enterprises, organisations, and the science and technology infrastructure and so on.

Innovation is highly uncertain. Innovation involves serious uncertainty, both in technological and in economic terms. It has very rarely been possible to predict the path of innovation, even in general terms. It is rarely possible to predict the economic outcomes for new products and processes. Enterprises very often make major forecasting mistakes, even when they are very well informed, and managed by highly competent and knowledgeable people.

Clusters are important, and reflect national and regional patterns of industrial and technological specialisation. Geographic clustering appears central to competitive advantage, a result that has emerged from a wide variety of studies.

Innovation is systemic. One of the most persistent themes in modern innovation studies is the idea that innovation by enterprises cannot be understood purely in terms of independent decision-making at the level of the enterprise. Apart from collaboration, discussed above, there are broader factors shaping the behaviour of enterprises: the social and cultural context, the institutional and organisational framework, regulatory systems, infrastructures, and the processes which create and distribute scientific knowledge, and so on. Taken together these factors make up a system, and system conditions can have a decisive impact on the extent to which enterprises can make innovation decisions, and on the modes of innovation which are undertaken. From a policy point of view the innovation system involves major problems of coordination that imply a central role for government in the creation of technological capabilities at country level.

In recent years policy makers have moved away from linear concepts of innovation, and this has been reflected in programme development, including the Framework programmes. However the full implications have yet to be incorporated into policy design and implementation – a challenge that remains ahead for Framework.

6. Reaching environmental sustainability

Environmental sustainability is an old topic, but it is becoming increasingly likely that geophysical and climatic developments will give it a higher place on the agenda of S&T policy. This must now be considered a key part of the current economic landscape.

The basic issue for S&T policy is the problem of initiating and sustaining environmental innovation in circumstances where innovation is constrained by the embedded technologies of existing innovation systems and technological regimes. Continued innovation is central to the solution of environmental problems, and such innovation must be radical in character. The reason for this is that most if not all of the environmental problems facing the world ultimately derive from the long-run processes of technological change that began with the first industrial revolution. The distinctive feature of economic evolution since the late 18th century has been persistent innovation, and while this has had spectacular effects on the performance of technologies and on human welfare, it has done so at the cost of significant environmental effects. Environmental problems, broadly speaking, derive from these negative technological effects, and will require further innovation if they are to be controlled or removed. But such innovation will be far from simple to achieve.

The main problem is that our current system of energy production, distribution and use, the hydrocarbon system, is deeply embedded in our technology and economy. Any innovation to replace it must in the long run be radical and system-wide. By definition, systems require coordination, but there is a big difference between the coordination required to establish a system, and the coordination required to run it. Where institutions, infrastructures or inter-firm connections are well established within a particular technological framework, the coordination needed for innovation is usually unproblematic. But where a new technology involves a major disruption, coordination becomes problematic, and this is where a public sector role comes in. Some innovations are radical with respect to existing procedures, engineering capabilities or technical knowledge bases – they involve major discontinuities, and 'shocks' to the existing technological systems. This type of view of change within a systems context is surely relevant to environmental technologies at the more radical level. If environmental innovation is seen as a kind of end-of-pipe clean-up technology then existing organisation and regulation systems are likely to be adequate. But if we see the task of environmental innovation in a more radical way, as shifting the fundamental technological systems on which the current industrial economy is based, then the coordination problems come to the forefront. A systems approach would suggest that the identification of co-ordination failures, the design of policy instruments to overcome them, and the development of relevant actors, are likely to be an important rationale for public policy intervention, and important also in deciding its scope and objectives. If this perspective is correct, then serious environmental policy cannot be carried through with market incentives only (such as tradable emissions permits) and will require the development of large-scale technological alternatives. These are likely to involve large and system-wide RTD programmes that must cross national borders. That is to say, it seems likely that some large mission-oriented programmes will be necessary if real alternatives to the hydrocarbon energy paradigm are to be found. The only potential European mechanism for this is FRAMEWORK, and so this may well become a key challenge in the future.

7. Conclusion

This overview of the changing landscape for FRAMEWORK has looked at four dimensions of change that are likely to have important policy implications in years ahead – the changing economic and technological landscape, changing macroeconomic conditions, the changing intellectual landscape (with respect to our understanding of innovation) and the changing environmental scene. Each of these areas suggests a continuing important role for public support of science and technology, and suggests also the continuing and indeed growing importance of the FRAMEWORK programmes. Of course other dimensions of change might be identified and debated. But it should of course be remembered that identifying change and challenges does not in itself say anything about how policies should be prioritised, developed or implemented.

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