SIG #3 Report on Economic Effect

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0 Executive Summary and Recommendations

SIG#3's work concentrates on the economic consequences of the NTW technologies. The work is rooted in the individual expertise of the Group members. Although we have communicated electronically, and met in small groups, there has been only one meeting of SIG #3. This reviewed the economic and social effects of converging transformational technologies on the 21st of May in Madrid, and arrived at a number of recommendations. This Version 2 is the result of comments by SIG #3 members and especially a very helpful and detailed critique by Mike Rogers. It is being sent to all HLEG Group Members to assist in the discussion of recommendations and conclusions at the 16-17th meeting.

We were asked to look at the economic effect of the converged NBIC (nano, bio, info and cogno) technologies. Our main conclusions are that it is too early to estimate the economic impact of NBIC convergence on the European economy in numerical terms, - for instance economists still disagree about the economic effect of the ICT revolution 60 years on.

We believe however that some useful statements can be made.

- We are in the throes of a societal transformation through the adoption of ICT (info), and much current discussion on "convergence" refers to the integration of computing and communication (mobile & fixed line) capability in single devices.

- Bio-tech is starting to change society, with changing demographics and new choices for society opening up.

- Nano technology is in current products where evolutionary developments eg better strength materials contribute to life cycle costs.

- Cognitive science has been used since at least the 1940's for the design of system-person interfaces, for instance in planes, but is not near changing society as yet.

- Bio and info technology are starting to use nanoscale techniques at least in the laboratory, while Cognitive technology applications are also starting to integrate with nano-scale bio systems

- We distinguish between NBIC convergence in scientific terms – with integration of basic science at a nano scale, where the capabilities become generic across old subject lines – and NBIC convergence in terms of using pairs or more of NBIC technologies to develop new capabilities. This latter we

refer to as CTTs (convergent transformational technologies) since we believe that significant advances often result from the intersection of two disciplines.

- **The SIG #3 Group believes that Europe will be significantly transformed by CTT's, though much of this will be beyond our 2020 timeframe.**

- Societal transformations have a global pattern. They follow the creation of businesses (anywhere) to develop new technology. At early stages of the development of new capability, many businesses are started by entrepreneurs or enthusiasts and later are taken over or fail – "Let a thousand flowers bloom". Europe is weak in creating new businesses: we have a number of recommendations to **strengthen Europe's capability in the diffusion of technology in general and to anticipate the impact of CTTs on specific industries by 2020.**

- Government funding (of all sorts) is a small percentage of research funding in US, Japan and Europe: so although many of our recommendations are "EC to ---", this will be in many cases the EC taking a seed-corn or facilitation role.

- The SIG #3 Group proposes that the non-traded sector (education, health, security, environment, etc) be taken as a focus for CTT research, with the intention of both improving Europe's economic and social performance, and creating products for the traded sector and hence exports outside Europe.

- **SIG #3 proposes that the research topics identified in the report from the scenarios workshop be used as the basis for further discussion.**

- **The Group recommends measures to increase the ability of Europe's citizens to work across national boundaries and disciplines, covering education, mobility and research infrastructure.**

- There are many factors which need to work together to implement the Lisbon agenda. **The Group saw a crucial need to provide an umbrella within which to discuss the directions and activities with Europe's citizens and the rest of the world. This umbrella has been named "KEY 2020", standing for Knowledge Europe Year 2020.**

We summarised our main recommendations for inclusion in the Final report as follows:

0. We endorse a "man on the moon" type of 10 year target to focus NBIC research, and felt that taking NLP into cultural translation, with automatic sensing and computation in a nano-scale device which could be worn in the ear, would be worth examining as a candidate. This is seen as an imaginative way to bridge the cultures of Europe and support a mosaic society.

1. Interdisciplinary research requires physical co-location of the researchers, at least initially during the time-consuming process of establishing a common vocabulary. These could be based on existing national laboratories, with open competition for laboratories to be recognised as an NBIC Institute, host projects and researchers. There should be relatively few, and they should be high status, able to attract researchers from across the world. The ERC could, for instance, fund Fellowships at these Institutes. Each Institute should incorporate Foresight activities in its domain, and actively support the Key 2020 programme for its domain. Each Institute is seen as domain specific, covering for instance health, energy and environment, education, and defence/security topics.

2. The group felt that Europe should take a lead in the world-wide diffusion of CTTs. Since knowledge travels on the feet of people, this suggests measures to increase the mobility of scientists, particularly to and from the developing world, joint projects on topics of mutual interest with developing countries, and also leading on international standards as an enabler for small countries to compete globally. The programmes with developing countries should be jointly funded by the Research Directorate and the Directorate with responsibility for European relations with developing countries. The international standards support could be a responsibility for the ERC.

3. There are many factors which need to work together to implement the Lisbon agenda. The Group saw a crucial need to provide an umbrella within which to discuss the directions and activities with Europe's citizens and the rest of the world. This umbrella has been named "KEY 2020", standing for Knowledge Europe Year 2020. This Programme should include activities and images to attract young – school age – people into science and technology or at least be less hostile to science and technology, based initially on the challenges of CTTs.

4. A key shortcoming in Europe is the shortfall in expenditure on research in te private sector, and the relatively low exploitation of research for economic benefit. The EC should set up a task force to define the specific improved framework conditions (intellectual property rights, market regulations, competition rules, standardization, financial markets, tax conditions, management) needed for research and innovation to increase private sector investment in CTTs and successfully transform Europe by 2020.

1 Introduction

1.1 The changing environment

As the world was transformed by cheap energy and reduced transportation of goods and services in the last century, two main factors are expected to transform this. These are demographics and information technology.

The world has lived at most times with an expanding population and more young people than old. This is changing, with immediate effect in the developed world, and by the middle of the century in most parts of the developing world. Much of the increased lifespan to date is through improved public health: future extensions of lifespan will be increasingly affected by decisions of individuals to adopt specific lifestyles or medical treatments.

RECOMMENDATION: EC should encourage futures work looking 50 years ahead.

There is discussion of a changing world order. If the US stays dominant, which impacts on EU, in particular as regards ethical concerns, EU will neither copy US drive nor ignore powerful streams (Asia, Latin America in particular). So we need to carefully assess and monitor the role of potentially economically dominant regions of the world on new performances or functions pulled by convergence.

RECOMMENDATIONS: Monitor the NBIC activity of US and Asia

Information technology has joined with cheap transport to implement many aspects of a global world, allowing jobs and goods to move around the globe. Competition between nations and increasingly "clusters" (Porter, 1990) is based on a mixture of factors contributing to the "cost" in time, money, quality, to the purchaser. ICT has also contributed to a changing business model, with a predicted decrease in large firms for many roles – particularly associated with innovation and creativity (Spectrum, 2004), (Camrass, 2003). ICT has also changed the balance of power between governments and groups of individuals.

1.2 Innovation and diffusion of new science and technologies

To understand the nature of technological change, we need also to focus on what causes innovation. We must analyse technology not only in terms of its effects, but as something which itself needs to be explained. We need to analyse the forces behind the development of new technologies – social, economic, cultural, etc.

New science and technology is the result of innovation, where Europe is less strong in many topic areas on most measures than the US (e.g. number of patents).

RECOMMENDATION: Strengthen economic analysis of socio-technical systems

It is useful to consider some case studies of diffusion of science into technology and society

- The fax machine is an example of timing and complexity weakening an essential right projection. Quick uptake was predicted, but initially it was too expensive and took too long to transmit a document. Eventually, 20 years behind plans, it achieved a mass market through improvements in price and performance of the converged computer and communications technologies.
- Microwave science was developed in the early 1940's and microwave ovens were discussed in the 1960's. But until two societal changes had already occurred – working women and chilled food industry – there was no market for microwave ovens. When the environment changed, in the 1980's the market for microwave ovens boomed, which at the technical kevel required the convergence of food science and physics. (Ringland et al, 1998)

RECOMMENDATION: EC Futures work should consider technology diffusion as well as technology development

In order to increase our understanding of resistance to new technologies, we should note that it appears to be a constant feature in the history of technology and European history. Three points can be made

- Resistance can come from many sources and should not be seen primarily in terms of Luddite labour resistance to innovation. The perception of negative effects is not something confined to particular groups; on the contrary, there are many potential points of resistance to innovation in business, public administration and politics, which have played important roles in the technological evolution of the European economies.

- Secondly, when resistance is seen in this broad way, it can really only be understood in terms of the interaction between the technology and its social context. It is not simply a matter of specific interests being threatened by new technologies, but a much wider process concerning the ways in which technologies accord or clash with social organisations, cultural values, and so on.

- Thirdly, resistance is by no means irrational. While resistance is invariably based on particular social concerns and interests, it can also be seen as a component of the more general processes by which society selects among technological options. Taken together these points raise questions as to what we understand by the term 'resistance' in the face of technological innovation.

How should we understand the nature of 'resistance'? An important point is that, from one perspective, resistance is simply part of the selection process through which new technologies are adopted or rejected. Modern market economies tend to generate many technological opportunities, but relatively few are diffused into widespread application; resistance can be seen as simply one of the ways (failure in the market is another) in which technologies fail to achieve acceptance.

Recent theories of technological change tend to follow an evolutionary perspective, in which the dynamics of technological change are based on some process which generates variety and diversity among technologies, and some mechanism which selects among the new varieties. It is important to note that in the evolutionary perspective the selection mechanism is not simply the market: it involves the whole complex of non-market decision processes, and there are many ways in which technology can be accepted or rejected by relevant actors. These non-market decision processes may involve, for example, public or semi-public procurement decisions, or political decisions to regulate, control or promote a technology. When there is continuous generation of technological variety, selection among alternative lines of technical advance is always necessary, and this selection process can easily be pictured as 'resistance'; but we should not see this as resistance to technological advance as such.

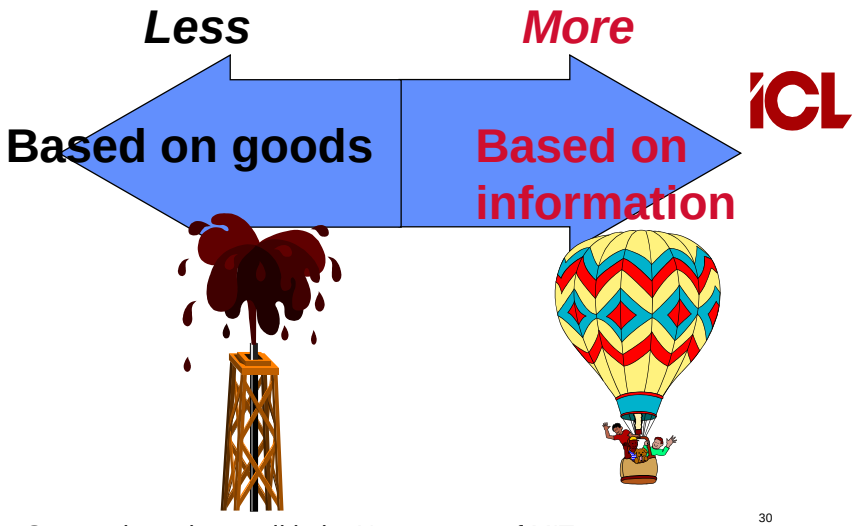
The necessity of selection is integral to the technological change process as a whole. Many modern technologies, in particular biotechnology, genetic modification and nanotechnology, are encountering severe resistance in Europe, and a deeper understanding of the character of this resistance is necessary if these technologies are to become genuinely useful in our society.

RECOMMENDATION: more work is needed on the source and nature of resistance to technology

The Group felt more focus should be given to diffusion as creation of the future (because rapid diffusion would be surprising), and understanding the process of diffusion itself. Below is a graphic used extensively by Nicholas Negroponte (Negroponte, 1995) to anticipate the diffusion of ICT: he proposed that industries based on information – such as Financial Services and education – would be transformed quickly, and those involving weighty goods such as oil and forestry would be unchanged. This organising principle was inadequate as adaptability turns out to be a key factor, with the private sector more adaptable than the public sector and business driven decisions – e.g. on supply chains – easier to mandate than changes in consumer behaviour. We felt that we could learn much from history, and that it would be useful to create a group of social scientists whose task would be to produce a synthetic retrospective analysis, with the intent of evaluating the consequences of each transformational technology in the past as well as in the present, and how far consequences have been achieved throughout the world.

The rationale is uncertainty: NBIC convergence is not with us yet.

Figure 1: Industries which change



Source: based on a slide by Negroponte of MIT

RECOMMENDATION - Research on historic impact of converging of Information and Communication Technology on social structures and aspirations

A key element in the history of innovation is that much of it explores not innovation but the diffusion of technology. Here there is a big and rather robust result: most cases of technology diffusion are slow, long drawn-out processes. For major technologies, it is common to find diffusion processes that last for many decades. For example, the time-lag from the discovery of the principles of lasers to widespread application was about 80 years; the wide application of the steam engine took about 100 years. Many such examples can be found, and they seem to point to a general phenomenon. It would be very unusual if widespread applications of nanotechnology occurred within the next fifty or so years.

Historical studies of technology transfer are of particular interest. Some people may think that studies of technology transfer in the remote past are irrelevant to current European concerns, because conditions were so different in the past. But that is exactly why such studies are useful: technology transfer involves moving a technology from one context to a new context where conditions are different. Historical studies are valuable because they increase our knowledge of the kinds of factors that were important, and of their relative significance – be they social, cultural or economic.

RECOMMENDATION - Research on the process of technology transfer and diffusion

Create a group of social scientists whose task would be to produce a synthetic retrospective analysis, with the intent of evaluating the consequences of each transformational technology in the past as well as in the present, and how far consequences have been achieved throughout the world.

The rationale is uncertainty: NBIC convergence is not with us yet.

RECOMMENDATION: explore « retro-foresighting ».

1.3 Timescales for transformation

There are a number of lead times: from a possible option to first and tentative use, and from that to wider uptake, co-evolution and structural change. For example, the rapidity with which new options are developed and used in software and ICT services (order of one year), compared with new materials, health sector, pharmaceuticals and related (five or more years), and agriculture and energy (ten or more years). Thus, there are different *tempi* in different societies, and the actual sequence of introductions is important (history matters, also in this respect).

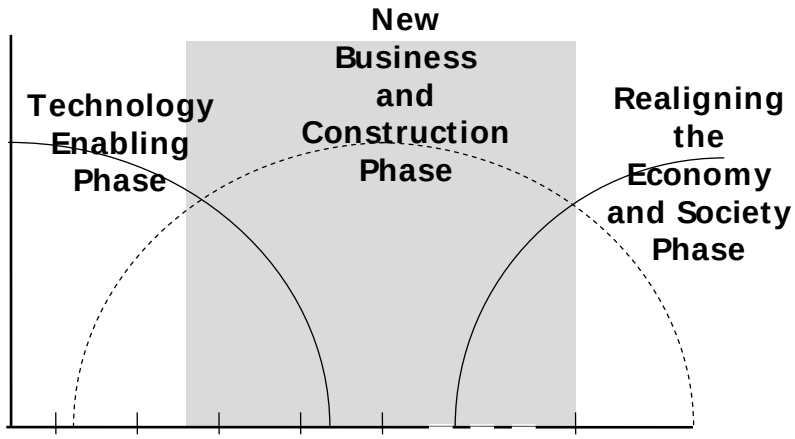
RECOMMENDATION: study the factors which can advance the adoption of new technology in different societies – both economic and social.

New functionalities have a different diffusion pattern from improvements in existing functionalities, as in the case of FAX, where Improvements in price and speed led to major, pervasive changes.

New functionality is surrounded by promises, and is often hyped to get enough support (with the risk of subsequent disappointment). Existing patterns have to be de-aligned to accommodate the novel possibility (cf. Abernathy & Clark on 'architectural innovation', 1985). This is precarious, and it takes time as well as needing protection in the first stage. Some military environments allow for pursuit of performance without regards of costs, and using defence procurement to drive high technology developments with spill-over into civilian life has been a route taken in the US.

Overall, a useful organising principle is encapsulated in Figure 2: waves of new or improved functionalities of scientific and technological development spawn new business opportunities, some of which may have a significant effect on the economy and society. The picture suggests that during the first phase of a technology being introduced to the market, the businesses that do so are probably new and may well fail – the Computer Industry as a model suggests that 1000 or so companies at the start of a new capability – for instance the PC – will over time reduce to "a few" global players.

Figure 2:Technology-induced change



Based on Gartner Group

St Andrews Management Institute (SAMI)

1.4 Applying to CTTs

The Information Society (ICT diffusion) is seen as only a first step towards a wider form of change of a more revolutionary type, to be associated to the notion of Knowledge Society (with a "new" economic model structure and dynamics). The second step in this direction is to be provided by bio and nano. The third and final step is Cogno (the door to Knowledge and Society) and it's melding into NBIC. This is a long term process (a century?) and the notion of convergence is associated with the progressive implementation of this "process". The final outcome provides a new "world view" approximated by the definitions of convergence, a revolutionary new concept of science and technology.

Against this background, at the moment there is very limited evidence of NBIC convergence (strictu sensu), and only embryonic "contacts" mainly on a two-by-two basis (e.g. between nanoscience and genetics).

So, as for ICTs, an observatory should be dedicated to CCTs applications, the speed of appropriation by the European population giving full support to research in the field of quantitative and qualitative knowledge, as an essential condition to secure economic research , policy agendas and evaluation.

RECOMMENDATION: Create a permanent observatory of economic and social effects of CTTs, linked to DG R&D and added to the mission of all European institutions: this could be an extension of the mission of the existing EITO.

Each of the four components (nano, bio, info, cogno, disciplines) are rapidly strengthening and are founding their own specific research lines (or demands), with

the obvious leadership of ICT. And although ICT is widely used in research on nano, bio and cogno science, this is not central to the scope of CTTs

The Group believe that "convergence towards NBIC integration" is a worthwhile endeavour for humanity in its quest for the Knowledge Society. This suggests that we should look at ways of accelerating the process.

Treating CTTs as generic at the scientific level has huge implications for regulations and public governance in general, which deserve being identified, specified and translated into policy agendas. In particular, the recommendations of the nano-technology community (ENA) as quoted in Section 2 should be applied across the NBIC domain.

RECOMMENDATIONS: Economic research on CTTs as generic at the scientific level and the implications for European policies.

We can distinguish between scientific and technological convergence:

- Scientific convergence, by increased interaction between components of the four disciplines that are already contemplating this possibility (e.g. AI, neuroscience, genetics,…) with a larger initial role of nanotechnology. This seems to offer molecular level convergence.

- Technological convergence, with the mediation of the engineering community, extracting new ways for solving societal problems from the independent developments of the four disciplines.

The US initiative mixes both approaches but puts more emphasis on the second (around the more controversial issue of "human enhancement"). Though the approaches are complementary, the scientific approach should receive initial priority (if only for precautionary reasons).

If technological convergence is also considered from the start, it will be necessary to keep track of possible orientations in the USA towards human enhancement marketable outputs, while developing a more European view, focused for instance on fields connected with general health (e.g. self-monitoring systems) and education.

Figure 3 represents these ideas, suggesting that social push is important for technology convergence.

RECOMMENDATION: basic science should be a focus of work in the nano, bio, info and cogno areas

RECOMMENDATION: EC and national governments to basic economic and social research on both scientific convergence and technological convergence

RECOMMENDATION: effective links between companies and technology research will help foster diffusion (the Norwegian model)

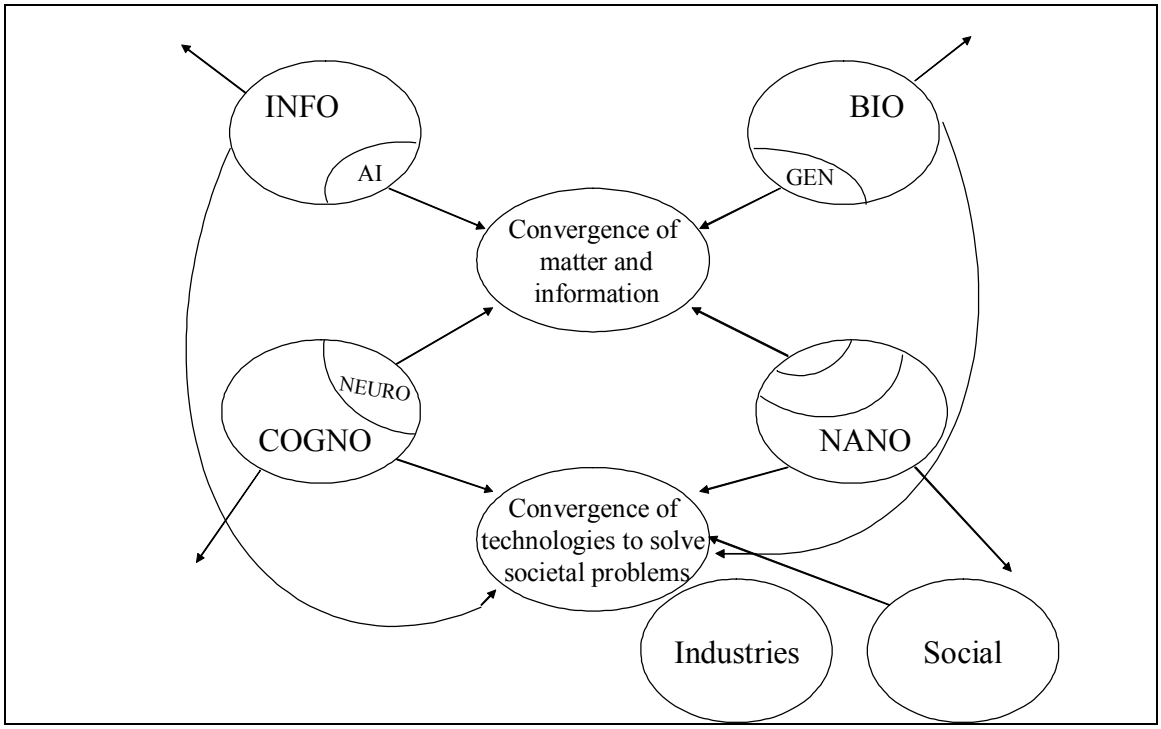
Much recent work on innovation focuses on the firm and stress the importance of learning and knowledge creation for firms' capabilities to innovate. This is an area which needs to be explored further: most theories of learning seems to focus on the individual so we need to broaden our approach to include organizational learning.

Another finding from innovation studies is that firms do not innovate in isolation but depends on interaction with their environment. One concept which is used to understand this phenomenon is 'network', or 'system'. We need to improve our understanding of such systems, how they work and what policy implications would follow. To study such complex phenomena requires that researchers from different backgrounds are brought together.

RECOMMENDATION: research is needed by multi-disciplinary groups on the mechanisms behind successful clusters and their application to CTTs.

RECOMMENDATION: focus on developing European clusters of excellence in CTTs.

Figure 3: Convergence at the levels of *science* and *technology*



1.5 On scenarios and NBIC convergence

The scenarios have a reasonable medium term horizon (2020) and therefore are essentially relevant to technological convergence.

In ***Global Capitalism*** the emphasis in human enhancement (USA) is reasonable as developments in this area are likely to stimulate high-priced market demands

(superior health goods) and at the same time raise expectations for price-inelastic demands associated to risk situations (military). The convergence takes place mainly between **I**nfo and **B**io, or **I**nfo and **N**ano or **B**io and **N**ano.

In both ***Competitive Europe*** and ***Regional Calm***, the economic system is more stimulated by public steering associated to the provision of public goods. The superior needs are also present, but this time they are more widely distributed via health, educational and cultural services. The linkage with Cogno needs to take place at an earlier stage: convergence of **I**nfo and **C**ogno becomes essential for a good interaction with either **B**io or **N**ano. In the final scenario, ***Alternative Lifestyles***, technology plays a marginal role.

Competitive Europe and ***Regional Calm*** are more likely scenarios for a specific European concept of NBIC development

1.6 Scoping the effect of NBIC

Currently economic outputs are visible or anticipated from each component. For instance

- INFO is practically changing all products and processes,
- BIO is modifying agriculture and the pharmaceutical industry,
- NANO has affected materials and is entering electronics,
- COGNO is likely to change some medical services

We suspect that CONVERGENCE will enhance all these developments and will induce synergistic new economic opportunities in all economic activities (pervasiveness).

In the same way that a number of factors contributed to the industrial revolution, and to the ICT revolution, we expect that evolution of society over the next century will be due to a number of intertwined factors – co-evolution. And we notice that, even in the case of the ICT revolution, already 60 years in, economists differ in their view of the effect of it on the world – or even the US – economy as expressed in terms of % of GDP growth.

So we prefer to think of the NBIC effect that we are studying as **CONVERGED TRANSFORMATIONAL TECHNOLOGIES, CTTs,** i.e. the Group believes that the joint effect of advances in NBIC science, the drive into technology and business, will change society, and at this stage our attention should be given to the forces encouraging or discouraging this transformation..

2 Opportunities

1.3 Scoping the expenditure on NBIC

NBIC is not yet a defined research or market area. The nearest sector which does have reported investment is nano-technologies. This now covers a much wider field than its original materials focus and covers a number of the electronics and bio-tech areas.

Cientifica reports on activity in the nano sector in 2002, (Cientifica, 2003)

- There were 430 companies in the US, 110 in Japan and 204 in the EU
- There were 104 research institutions and Universities in the US, 88 in Japan and 142 in the EU
- There were 396 research institutions and Universities world-wide, 122 large companies, 89 JVs, 497 start-ups and 146 "others"
- VC funding was worth e173M[20] in the US, e38M in Europe
- Government funding played a small part in US, Japan, Europe, in US and Europe VC funding was over 80% and the rest corporate, in Japan corporates dominated with 89% of funding.
- ENA (ENA "Use it or lose it, 2004) suggests that EC research funding is approximately e700M over 4 years, compared with 2002 government expenditure in Japan of about e625M and in the US of e500M. When other sources of public research are taken into account in the US and in Europe, it is not clear that there is a funding gap for research.

These numbers do however suggest a weakness in VC funding and a very wide set of research institution and University players in Europe, and less private sector activity in general. This suggests that the private sector industries such as chemicals and pharmaceuticals, textiles, cosmetics, tobacco, ICT, biotech, aerospace, energy, automobiles, energy, may be lagging in Europe.

ENA (ENA, 2003) emphasises the role of scientists and government in communication with business and the public; European businesses are also concerned about regulation. The concerns are about their appropriateness, and especially in Europe, the diversity of approaches between countries. ENA sees a role for the EC in both funding and in regulation. Its conclusions are:

- Europe needs a dynamic and co-ordinated approach to ensure that existing world class academic work is effectively transferred to European industry
- Europe is not getting its message across (on the applications of science and technology)
- Regulatory bodies need to look beyond nano-scale technology and understand the uses – there is no nano-technology industry, simply a collection of diverse businesses using the phenomena. (For instance, one of the oldest applications is in paints as titanium oxide, used for road whitening etc)

[20] $ figures in US reports have been expressed in euros at an exchange rate of 1.2 $ = 1 euro

- The EC needs to focus on translation of world class science into economic effectiveness, the instruments in Europe are far too biased towards research

An important issue for modern technologies is whether or not the real benefits of a technology derive from its creation or its intelligent application. One of the key points to emerge from studies of the historical diffusion of innovation is that smaller countries in particular do not necessarily need to be technology creators to become rich countries. What seems to be necessary is creative adaptation – the ability to deploy advanced technologies as tools for upgrading industries that may be quite mature or traditional in character. (This is certainly an important part of the development of the Nordic area, but it also applies to many other countries - such as Canada, Benelux, Australia – which have played little part in the major technological revolutions, but have succeeded in deploying the technologies that result from them.)

There is an important question about modern technologies related to this point. In some cases, such as ICT, it appears that countries can follow an "import and adapt" policy for the use of the technology, and can grow on the basis of being an intelligent user of technology supplied from outside. But does this apply to technologies such as biotechnology and nanotechnology? Are these technologies cases in which benefits can be appropriated by using the technology without mastering its underlying core?

RECOMMENDATION: Assess the right combination of creation versus transfer (import) of technologies as an input for European R&D policy guidelines for the long run

RECOMMENDATION: EC to look to prioritise funding of Research Institutions and Universities to create world class players

RECOMMENDATION: EC to stimulate VC funding

RECOMMENDATION: EC to encourage start-ups and small companies

RECOMMENDATION: EC to take a lead on risk assessment and regulation

RECOMMENDATION: EC to work to translate academic research into economic effectiveness.

The US National Nanotechnology Initiative suggests that a trillion euro worth market for products and services with "nano inside" will exist by 2015 – this compares with the US GDP of e9 trillion today – i.e. about 10% This re-inforces our recommendation above, to look at the transformational aspects rather than the effects on factors such as GDP.

2.2 Europe's economy: tradable & non-tradable sectors

Europe is at present a multicultural society. Migration has exposed more citizens to different cultures, and the effect of enlargement will be to add to mobility and increase this. Europe needs to move towards a intercultural or mosaic society where mutual respect based on communication and understanding could find some basic

shared values such as human dignity, respect of human rights and democracy - thus creating the picture of the entire mosaic.

RECOMMENDATION: Need research on « how to move to an intercultural society? And the role of CTTs in this»

RECOMMEMDATION: measures to increase the ability of Europe's citizens to work across national boundaries and disciplines, covering education, mobility and research infrastructure.

While the single European market makes available the same goods to all citizens, life styles are very different in Stockholm and in Rome (not only for climatic reasons). Economic products (goods and services) are not all tradable; many of them are fixed or nearly fixed. Of course services relying on infrastructures are directly linked to their location. Most services are non tradable even if often open to competition (by new local operations). Socio-technical systems and operating systems (the ways of mixing infrastructures, goods and services) are non tradable. They are the result of democratic decisions in specific territorial units, and are culturally driven.

Democratic decisions also establish for the non-tradable economic activities the role of market forces. Educational, health, or environmental services are non tradable but can be provided in a competitive market context.

The dichotomy between tradable and non-tradable behaviour can be extremely pronounced (Japan), but the two components are related (the "cost" of non-tradable activities weights upon the tradable activities). The diversity of European democratic choices (the differences between Stockholm and Rome), shows however that "competitiveness" in the tradable sector, is not too seriously affected by the preferred mixes for non-tradable activities expressed by the local populations. The European application of the mutual recognition principle is not leading to intractable economic disequilibria (intra-European delocalisation processes, when they occur, are mostly dependent on wage differentials). The diversity of infrastructure does not seem to lead to inefficiency, with notable exceptions.

Exceptions seem to arise in areas where interchange of information is important – as in effective telephony, road systems and patent laws for instance (Porter, 2003).

RECOMMENDATION: research on role of infrastructure (widely defined) in economic effectiveness and especially CTT diffusion.

RECOMMENDATION: Stronger involvement of economists in research (including evolutionary ones) on both the technology and societal evidence base and the associated policy research.

There are early indications that, by virtue of massive public appropriations in the fields of nanotechnology; biometrics and ICTs, standards will be set quickly by the beneficiaries of that public spending. Europe should not be left behind, as a strategic competitive issue for the future.

RECOMMENDATION: Stimulate active EU early participation to worldwide institutional and not (yet) institutional standardization bodies as a strategic issue to R&D and market.

2.3 Tradable goods

For tradable goods the interest is centred on the way of increasing their Knowledge content (changing the product), or on the way of reducing their input cost (changing the process). These tradable goods evolve in a global context characterized by specific market structures; the economic gains of the innovations are distributed to the consumers (lower prices, more quality for an equivalent price), to the producers (as increased returns to their investments) or to the developers of the technology (from their IPR). The final outcome of the power struggle between these three types of agent has macroeconomic implications (not to be discussed here).

This rationale of tradable goods is applied to many INFO products (computers, mobile phones, etc), to an increasing number of BIO products (for the production of GMO, for pharmaceuticals) and is starting for some NANO products. Some of these products are intermediate (used for the production of others), other are final (for consumption or investment) but the logic of creation and distribution of innovation gains is always the same, and their production follows the laws of market competition. As already experienced with INFO, we should expect restructuring of industry as NBIC develops, with new production activities of tradable goods.

A number of industry sectors are often discussed as being affected by NBIC, e.g.:

- Pharmaceuticals
- Manufacturing/engineering
- Electronics and optical devices
- Materials
- Defence
- Entertainment
- ICT

We have not however been able to find any systematic analysis which expresses this in terms of size, timescale, effect on jobs, potential for exports from EU, etc.

RECOMMENDATION: EC to fund research to examine opportunities in each traded industry sector in terms of jobs, exports, and contribution to non-traded sector

There have been a number of concerns expressed on the security and health of labour forces exposed to nano-particles in manufacturing, and the need for tracking CTT modified organisms and materials across international boundaries.

RECOMMENDATION: EC to examine the regulatory system for international trade and Health and Safety for products developed using NBIC technologies.

The success of Nokia in exploiting the international standards process to drive the creation of a major business has been widely commented, and the opportunity for Europe in taking this route for CTTs should be explored.

RECOMMENDATION: EC to explore what international standards are required for CTTS to be adopted and ensure European companies are well represented on the appropriate (or new) bodies.

The creation of a single patent across the EU as a key point of the Lisbon agenda has faced national deadlocks. But at the same time, the international gap between registered patents in CTTS in the US and Japan (the least not being for space applications) is increasing quickly. European regulation on patents needs to be reviewed quickly as regards EU needs and positioning in the future economic and legal relationships.

RECOMMENDATION: Create a real Common European patent office under full EU public regulation, involving transparent and independent litigation process.

2.4 Non-tradable economy

For the rest of the economy covering activities that for one reason or another are out of the global trade process (their products cannot be traded or the trade is necessarily of a local character) the rationale for the innovation process is different.

Many of these activities have a public interest service character; others while operated on a private basis and in a competitive framework, have to be designed for meeting local needs rather independently from global competition. Both are driven by the characteristics that are at the root of diversity.

While the share of internationally traded goods in the total of tradable goods is continuously increasing as a result of globalisation, the share of the tradable goods sector in developed economics is most probably decreasing as they move towards more service oriented structures.

Furthermore some of the "superior needs", like education and health, are mostly non-tradable and follow the pattern of democratic social decision - making; social structures essentially define the nature and the distribution of innovations gains.

In taking a focus first on actions enabling societal outcome and including promotion of diffusion whenever societally desirable, the Group believe that we should start with non tradable products because most of economic activity is of non tradable-type. When we consider how to organize non tradable sectors in the most efficient way, in the context of convergence, we find that one lever is the supply push/demand pull for non tradable collective goods.

RECOMMENDATION: Assess the supply push/demand pull for non tradable collective goods.

Obviously the social steering of the NBIC development mainly refers to the possibility of promoting technologies that could be integrated into the non-tradable production systems, leaving the decisions on tradable productions where they belong (in the private enterprise duly bounded by appropriate regulations).

TABLE 1: Products & Services

Tradable	***Non Tradable***
● New products: (BIO chemicals, NANO-BIO implants…) ● New inputs for productions processes: (BIO-Agri, …) ● New inputs to operating systems: (nano sensors, …)	● New services: (INFO-COGNO educational systems, environmental surveillance systems, …) ● New operational systems: (NBIC personalized health monitoring, …)

NANO and BIO deal mainly with the production of artefacts, and so does the INFO hardware; however a substantial part of INFO and all COGNO are really associated to the notion of services. The NBIC technologies that incorporate cognitive elements,

and are more directly relevant for the Knowledge Society are also those more closely related to what we have called "non-tradable" activities. Most "tradables" are expected to come from NANO-BIO-INFO convergence; many of these products may be essential components to non tradable systems (e.g. to medical services).

The economic success of "tradables" seems to be subject to a great extent to the successful development of non-tradable uses (Society). This suggests that we should concentrate on this second, where of course the returns are more "social" than "financial" (at least initially). This is coherent with the results of the survey on quality of life conducted by SIG 1, as it appears that the more robustly expected contributions of NBIC have to do with the "non-tradable" side of the economy. These sectors are robust across all four scenarios – though with different nuance in each – and are:

- education,
- health,
- infrastructure (telecommunications but also transport),
- environment,
- public safety

These topics could be "non-competitive" and provide a basis for international co-operation. It would be essential to have both regional studies (e.g. for Nordic) where cultural factors might be similar, and across regions (e.g. Italy and Sweden) to examine cultural differences.

RECOMMENDATION: examine social uses of CTTs and hence derive product implications to drive policy, in both culturally homogeneous regions and across them.

Energy supply for 2020 has been highlighted as an area for research, using a qualitative approach including complexity and uncertainty involved by multiple combinations of transformational technologies, and the impact of micro-sources of energy on infrastructures. This needs to be taken in the context of the overall position in say 2050, when the picture becomes very different from now: 2020 represents a transitional stage.

RECOMMENDATION: EC to fund EU wide study of energy supply in 2020

2.5 To do's: Public awareness, governance and skills

Governance and public awareness to be properly addressed (fully involving civil society). Pubic awareness of and attitudes to science have been identified as one of the major differences between the US and Europe (George Gaskell, 2004). The Group felt that many of the recommendations would be more effective if implemented within a communications programme as umbrella. For instance a KEY 2020 communication campaign for the future converging transformational technologies (CTTs) European policy – Knowledge- Europe Year 2020) would allow the anticipation of the effect of economic and social actors to be elaborated in a very detailed and systemic way. Among other instruments, a simple and mnemonic wording should be a « flag » covering multiple aspects of a one and only goal (to be put through Lisbon Agenda review in spring 2005).

While the words 'society' and 'the public' are widely used, they tend to be too broad, covering disparate phenomena which need to be addressed in their specificities. The EU population is also very diverse and the KEY 2020 campaign would need to be mapped in terms of the messages able to speak to different societal and cultural values. This can be done on the basis of already existing data at the EU level in quantitative terms and should be also based on research which is already existing for different parts of EU such as Mediterranean area , Nordic areas etc

RECOMMENDATION: KEY 2020 CAMPAIGN for public awareness of both the technological possibilities and the governance issues.

RECOMMENDATION: KEY 2020 CAMPAIGN tailored to cultural needs

Some citizens and individuals are resistant to new technologies, and this is more marked in an aging population. We need to increase understanding of reasons for resistance to technologies by public, and devise social instruments that could be used to bring the scientific community in closer contact with the public to avoid the tendency in the scientific community to be too optimistic about the potential risks. This suggests the creation of scientific documentation segmented by population to be addressed as regards CTTs and the need to take into consideration Subsidiarity and specific actions in order to get out of blind alley/ dual optimistic/pessimistic approach of the NTW.

It is very important to the future of Europe to get out of polarised attitudes due to incorrect information on NTW. To do this, clear and scientifically sound information is needed and has to be adapted to the different social groups existing in Europe

RECOMMENDATION: initiative of a multilateral, transparent and democratic task force on CTTs as a means to improve dialogue between scientists and citizens within KEY 2020.

One should not consider good practices and « softlaw » as a final outcome of international dialogue, but as an interesting but limited first step towards an international, transparent and democratic dialogue on CTTs planetary issues (including ethics, risk assessment, information sharing and peer to peer reviews). CTTs international governance at an intergovernmental, fully supplied by civil society involvement, is unavoidable well in advance of year 2020.

RECOMMENDATION: initiative of a multilateral, transparent and democratic task force on CTTs as a means to improve international dialogue, propose and implement peer reviews and present attractively the EU choices.

There is a shortage across the Western world of qualified research scientists. The size of the effect can be guesstimated from a recent headline in the UK Financial Times "Visa delays cost US $30BN (e25M) in 2 years" – this was the estimated loss to the US economy of the relative drying up of research scientists immigrating into the US.

Europe can take advantage of this change in availability of scarce manpower to augment our own. A European visa for scientists is close to adoption (see for instance the report in The Scientist, 2003)

RECOMMENDATION: EC to actively encourage immigration of scientists and engineers who might previously have gone to the US, and/or sub-contracting research outside Europe

Our lack of scientists starts in the schools. We should involve primary and secondary school teachers in understanding and CTTS; create tools of teaching the future and a citizen's attitude towards the long term. These are the levels where future citizens are prepared. The need is hence for educating the young to look ahead at their future and that of their social and cultural environment with different tools such as using imagination to bring far futures in time and place closer. Tools for teaching in a simple but scientific way what the NTW is about and what it may bring in positive and negative terms

RECOMMENDATION: EC to actively encourage creation of programmes reaching schools under KEY 2020

Young people need to have tools to help them imagine the future, be educated to think to the future and make it present. This has research and pooicy aspects which need to be considered.

RECOMMENDATION: Develop approach to young people's imagination under KEY 2020.

In the CTT world, we need to create institutions specialized in interdisciplinary working to get together: people will have to be prepared for convergence. This needs the promotion of multidisciplinary of teams and education There has been much discussion of the skills needed for working across traditional subject boundaries: opinions differ as to whether new undergraduate degrees are needed or whether a series of "conversion" masters degrees are more appropriate.

RECOMMENDATION: EC to sponsor experiments in cross-subject working and monitor criteria for success of inter-disciplinary teams, including specifically the role of co-location.

International cooperation in 7th F: Cognitive sciences and technologies (combined with other CTTs) as a powerful means of inclusive international cooperation, respectful of diversity, and a tool for world integration, in complement of social

sciences. Intellectics (ontology and knowledge, or AI plus computer science), linguistics and development of the « trading zone » between scientific disciplines is one of the key conditions on which interdisciplinary working relies.

RECOMMENDATION: Research on how to promote and accelerate mutual understanding on " vertical dictionaries" as a first step towards common language (c.f. the image of nanocajun, in NBIC 2004 proceedings).

Diffusion of science and technology into start-ups and corporates seems to work less effectively in Europe than in the US and Japan: there are some good paradigms for this, as the HLEG saw in Norway.

RECOMMENDATION: European research communities should consider setting up Advisory Boards from interested companies at early stages of the research

People will have to be ready for the wider understanding of the workings of the brain as advanced through Cognitive Science, and the potential that gives for improving the capability if groups of people to work (or play) together. We need research on the enhancement of firm's organization and knowledge: which effects/ ability of appropriation of CTTS by the labour force? Which expectations on effectiveness, competitiveness, global mobility?

RECOMMENDATION: research on organisational capability in the CTT world

3. Recommendations from the MADRID meeting

The Group believed that many of the recommendations appropriate for NBIC/CTTs apply to the whole 7th Framework Programme, and that these could be divided into recommendations on

- research infrastructure: this needs to be actively designed to foster both international and interdisciplinary working in order to achieve competitiveness on the world scale. The infrastructure also needs to include mechanisms for evaluating the economic effect of research.
- Governance: a headline is the need for a single European patent system
- Public awareness: around a single flagship KEY2020 campaign (Knowledge Europe Year 2020)
- Diffusion and take-up by industry: research on diffusion of technologies, particularly in the non-tradable sector, and the effect of that on the traded sector and competitiveness

Recommendations on research topics are specific to NBIC:

- Economic research on CTTs as generic technologies and the implications for European policies
- Study the impact of micro-sources of energy on infrastructures, conditions of energy supply in 2020
- enhancement of firm's organization and knowledge: which effects/ ability of appropriation of CTTS by the labour force? Which expectations on effectiveness, competitiveness, global mobility?
- Intellectics (ontology and knowledge), linguistics and development of the « trading zone » between scientific disciplines as one of the key conditions on which interdisciplinary working relies

In addition the SIG #3 Group endorsed the research topics identified for the ***Competitive Europe*** scenario, and those robust across all scenarios.

The recommendations below have also been included in the appropriate place in the previous text: the numbers refer to their order in the SIG #3 working paper.

3.1 Research topics

10	EC and national governments to basic economic and social research on both scientific convergence and technological convergence
16	Need for research on « how to move to an intercultural society? »
21	Economic research on CTTs as **generic** technologies and implications for European policies.
2	Stronger involvement of economists including evolutionary ones
24	Study the impact of micro-sources of energy on infrastructures, conditions of energy supply in 2020, and on future choices for fabrication process (decentralization, delegation...) .
25	Intellectics (ontology and knowledge, or AI plus computer science), linguistics and development of the « trading zone » between scientific disciplines as one of the key conditions on which interdisciplinary working relies. How to promote and accelerate mutual understanding on « vertical dictionaries as a first step towards common language (c.f. the image of nanocajun, in NBIC 2004 proceedings). How to put together the CTTs fields of knowledge?
26	« People will have to be ready for Cogno: we need to make research on enhancement of firm's organization and knowledge: which effects/ ability of appropriation of CTTS by the labour force? Which expectations on effectiveness, competitiveness, global mobility?

3.2 Research infrastructure

N°	Title
3	Create institutions specialized in interdisciplinary working to get together: people will have to be prepared for convergence. Promote multidisciplinary of teams and education
12	Take initiative of a multilateral, transparent and democratic task force on CTTs as a means to improve international dialogue, propose and implement peer reviews and present attractively the EU choices.
13	Create a permanent observatory of economic and social effects of CTTs, linked to DG R&D and added to the mission of all European institutions.
15	Stimulate active EU early participation to worldwide institutional and not (yet) institutional standardization bodies as a strategic issue to R&D and market..
27	International cooperation in 7th F: Cognitive sciences and technologies (combined with other CTTs) as a powerful means of inclusive international cooperation, respectful of diversity, and a tool for world integration, in complement of social sciences.

3.3 Diffusion

5	Give more focus to diffusion as creation of the future (because rapid diffusion would be surprising), and understanding the process of diffusion itself
6	Assess the right combination of creation versus transfer (import) of technologies as an input for European R&D policy guidelines for the long run
7	Assess supply push/demand pull for non tradable collective goods.
9	Strengthen economic analysis of innovation process. Give consideration to socio-technical systems as well
20	Enter the economics of non rival goods as related to convergence of ICTs and cognitive sciences and technologies. Focus on the knowledgeable one's surplus instead of the consumer surplus as a full part of industrial economics of the 2020's.
22	More work has to be done on how a technology acquires a strong potential pervasive skill, as an important input to improving scenarios for the future.
28	Explore « retroforesighting ».

3.4 Public awareness

11	Identify a KEY 2020 communication campaign for the future converging transformational technologies (CTTs) European policy – *Knowledge- Europe Year 2020*).
19	EU population has to be mapped in terms of the messages able to speak to different societal and cultural (which means choice of values) levels.
4	Increase understanding of reasons for resistance to technologies by public. Devise social instruments that could be used to bring the scientific community in closer contact with the public to avoid the tendency in the scientific community to be too optimistic about the potential risks.
18	Create scientific documentation segmented by population to be addressed as regards CTTs.
17	Involve primary ands secondary school teachers in KEY 2020.
29	How to teach young people how to imagine the future, educate them to think to the future and make it present. (Research and policy aspects).

3.5 Governance

1	Governance and public awareness to be properly addressed (fully involving civil society)
14	Create a real Common European patent office under full EU public regulation, involving transparent and independent litigation process.
23	Monitor he NBIC programmes in US and Asia.

4. Conclusions

4.1 The significance of NBIC

We concluded that the technological convergence of Nano, Bio, Info and Cogno technologies – that is, the ability to manipulate animate and inanimate matter in a controlled way at a nano-scale – will have significant impact on society and the economy.

We felt that this effect would be transformational rather easily measured in GDP or other "like for like" measures, and so adopted the term Convergent Transformational Technologies to describe our sphere of interest.

The effect will be seen in specific industries and non-traded sector activities before changing society, and we recommend research on these intermediate stages since they have a shorter – say 2020 – timescale.

We do not disagree with the US estimates of about 10% of the economy affected (by nanotechnology widely defined) by 2015.

4.2 What should Europe do?

In terms of research topics, the Group accorded with the output from the scenario workshop in terms of priorities, and added some specifically on socio-technology.

Some changes in research infrastructure are indicated. Europe's research is scattered across many institutions and we conclude that a more focused, "centre of excellence" approach is required. We also recommend measures to get cross-disciplinary collaboration including co-location of research and developments in the curriculum but also suggest that these should be monitored to see "what works and what doesn't".

Europe has an opportunity to lead efforts in standardisation, which can give small countries a level playing field (as in Nokia's success in mobile phones with GSM). An essential early standardisation for Europe is in patent laws.

Europe's private sector – whether venture capitalist or corporations or start-ups – shows signs of being less active than that in the US and Japan. This is a major weakness since much of the science and technology will be adopted globally.

There is evidence that public attitudes to science and technology are less positive in Europe than in the US: we suggest a "KEY 2020" media campaign to re-enforce the Lisbon agenda.

4.3 The Role of the EC

The EC is seen as essential in co-ordinating the national governments with a well-argued case for tackling the points above and implementing the detailed recommendations found in this report. To this end we have recommended a number of Task Forces.

The difficulties of cross-disciplinary working have been illustrated by the time it has taken for the HLEG to develop coherence: we recommend that the HLEG be asked to implement Task Force actions beyond October 2004.

Eof

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