The Impact of Converging Technologies on Regional Innovation

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ABSTRACT

The phenomenon of Convergence has been acknowledged as having a significant impact on development of S&T and ultimately on the quality of life. As the convergence is seen as desirable, policies have been put in place to enable it. On the other hand, in parallel in the past several decades, innovation has come to the attention of theorists and business managers alike as being crucial to economic development. National Innovation Systems and Regional Innovation Systems have been over the past decade analysed and measured mostly from the point of view of resources, institutions and knowledge transfer programs. There exists a relative lack of robust methods to analyse RIS and NIS as complex adaptive systems stretching across disciplines. Also there are no models either causality testing or prediction ones. The engineering of complex systems requires consideration of an intricate web of components and their interaction in diverse social and technical environments. Now-a-days the social, behavioural and economic sciences face extraordinary opportunities to address both next generation research challenges and today's social demands. The main goal of all innovations is to create new wealth, build strong local, regional and national economies and improve the national well-being.

Background

The convergence of formerly distinct industries is occurring at a rapid pace. Technological development has led to convergence of knowledge in education and theoretical conception, in markets and sometimes in the products and services. The main enabler of this process is the information technology which is a GPT. Information technology converges with

telecommunication and information content. Each worker in these fields becomes a node in the network and the performance of one node has influence on the whole network in an orchestrated dynamism (Poesposoetjipto, 2004). The relationships between nodes provide a platform for convergence with other technologies such as biotechnology, nanotechnology and cognitive science.

Stages in Development

Research and Development: A company's first steps in producing and marketing a new product involve the process of research and development (R & D). During R&D, small-scale experiments take place as scientists and laboratory staff work together to develop new products, which offer promise. In biotechnology R & D is a lengthy process (lasting as long as one year or more). Researchers concentrate on new discoveries, and scientists and technical staff engage in process development and the scaling up of production resources to conduct full-scale manufacturing.

Manufacturing and Production: The manufacturing process is expanded to produce large quantities of product, which may include creating a manufacturing facility.

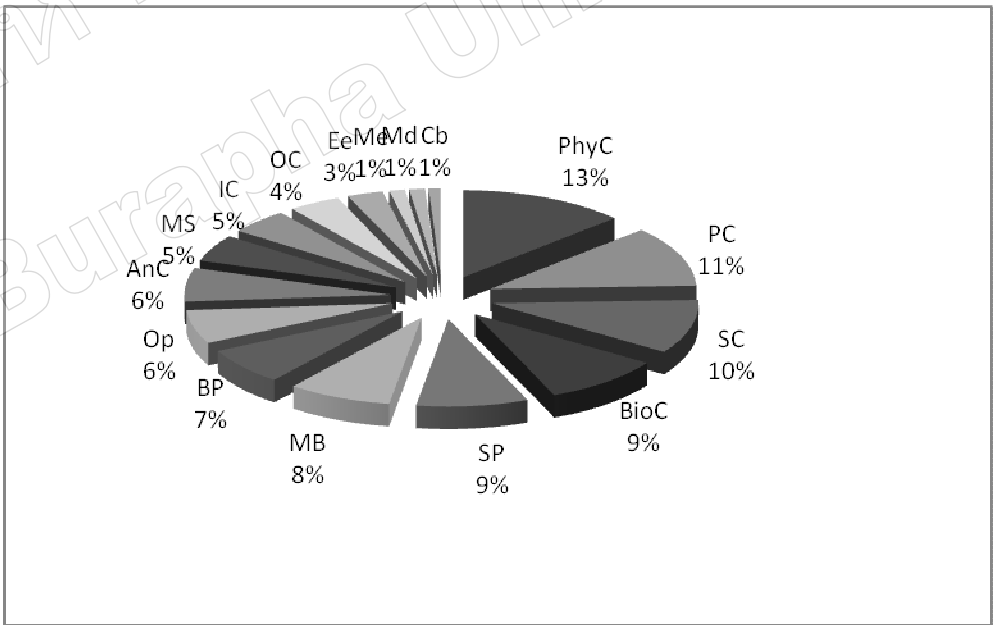


Figure 1 Commercialisation of products: Relative impact of contributing fields to NSTE.

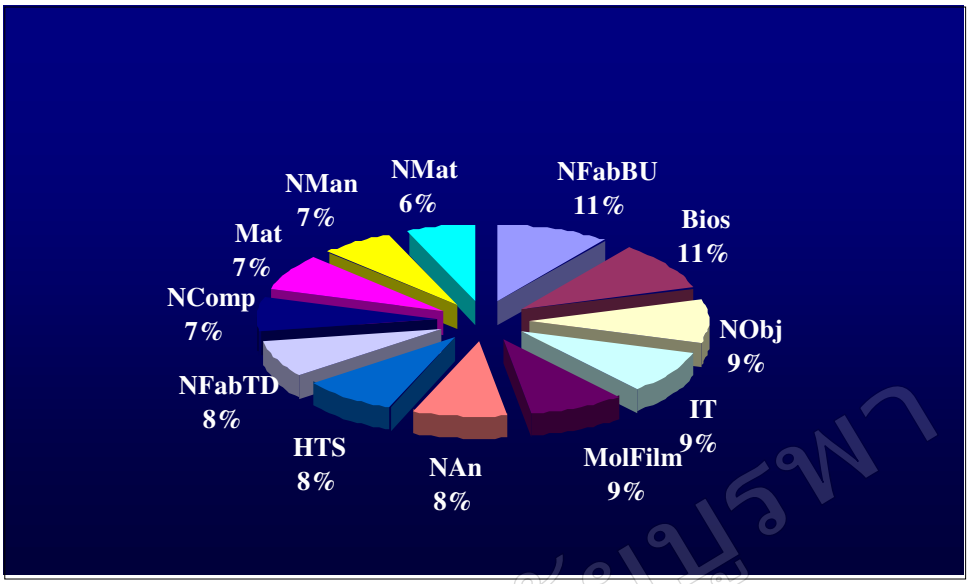


Figure 2 Relative impact of connected NSTE sectors.

In recent decades science has been a major source of new technologies we can call this trend science pull. According to Corrocher, Malerba and Montobbio (2003),

Technologies evolve in response to the interplay of history agents, institutions and market demand and this evolution does not follow a pre-defined linear pattern (Corrocher etal., 2003). In the science pull model demand is not developed and scientists and engineers form expectations about the possible demand for their product. For that they need signals from the possible customers in the existing markets. In the cases for radical new innovations new markets develop meaning the innovations serve a need which has never been served before or meet existing needs in new ways. The latter is the case for nanotechnology with applications in medicine, the nanodrugs meet existing needs but in radically new ways. Information technology on the other hand created an entirely new market for computers and software. The need and the demand have grown since and it reached a point where the demand is restrained by the limits on the supply side. Tushman and Anderson (1986) point out that technological change is a cumulative process punctuated by major advances. In this context we have to delineate between technological discontinuities that generate new product classes (computers, nanomaterials) and technological discontinuities that generate

process substitution (in case of nanotechnology it will generate process substitution in microelectronics for example).

Co-evolution of Biotechnology, Information Technology and Nanotechnology.

In recent years companies within biotechnology have been interacting with high-tech companies and using technology originating outside the traditional biotechnology market (Ernet & Young, 2000). Convergence of these three technologies has three drivers:

1. Material unity at the nanoscale
2. The creation of a hybrid market place
3. Technology convergence that is building upon itself in which companies with a product for one market are now leveraging that technology in new areas.

This way the innovation that supports an individual market can have impact on the strategic directions of other markets (Ernet & Young, 2000). Innovation is part of an evolutionary process of technical, institutional and social change. Recent developments in nanotechnology are transforming the fields of biosensors drug delivery, medical devices and diagnostics. A new generation of advanced biosensors has begun to emerge with two new major characteristics: much enlarged multi-analytical capability and better sensitivity. In the same time bioinformatics has advanced. There are two problems which some countries encounter: the high costs of such developments and a low presence of multinationals.

Network Convergence

The term convergence is commonly expressed as the ability of different network platforms to carry similar kinds of services and goods or as the coming together of consumer devices such the telephone, television and personal computers. The network convergence is the most present today and it led to the information society. The network platform and the user environment constitute two elements of the value chain extending from content creation to packaging, service provision and delivery to the customer. The value chain is important in analysing the behaviour of firms and markets in the light of convergence. Firms tend to be present in one or more elements of the value chain, and the shift toward convergence is apparently going to lead to the extension of firms'

activities. This is already seen in mergers, acquisitions and alliances. There are four levels of change as a result of the convergence: knowledge/science, technology, industries and markets.

Convergence in Knowledge

Convergence in knowledge can be achieved through interdisciplinarity. However despite the real or perceived benefits of interdisciplinarity, important barriers too often impede its appropriate management. For instance, regardless of the quality of their work, interdisciplinarians often experience difficulties securing research grants, going on exchange programs, publishing gaining recognition, securing a job, or being promoted. Researchers who identify themselves professionally with cross-disciplinary category face the entire panoply of gate-keeping mechanisms, which by and large favour existing disciplinary categories (Nissani, 1997). Furthermore, the promoters of interdisciplinary research and education must overcome their colleagues' resistance to change.

The main fundamental barrier to interdisciplinarity is education. Moreover, as knowledge is the main strategic resource for ensuring growth in developed countries, the universities as main producers of knowledge play a very important role in economic growth. This knowledge is both "soft" - ideas-and "wet" -skills. Since the most innovative ideas and products are not confined to one field, the emphasis on interdisciplinarity has to be applied to all levels of infrastructure.

The rationale for interdisciplinarity in education (especially in the undergraduate Curriculum) flows from the intention to provide the learner with flexibility of mind and openness to other ways of thinking through the interaction with different conceptual structures, different methodologies and different kinds of knowledge of other disciplines.

Another trend is toward basic research by both the government and private sector companies. This trend is noticeable in many countries but Japan is one of the more advanced in this regard. In Japan this trend started in the 1980s with the steps taken in 1981 to inaugurate the Technology Research and Development Program for Next-Generation Infrastructures to replace the Program for Large Scale Industrial Technology. Another move was the establishment of the Exploratory Research for Advanced Technology (ERATO) by the Science and Technology Agency. Such programs have the emphasis on the ideas of researchers and inventors rather than

their ultimate purposes and applications (Ikezawa, 2003). This orientation toward the basics is part of a general trend toward convergence of knowledge.

Convergence in Technology

Convergence in knowledge is not necessarily going to lead to the same degree of convergence in technology. The enabling role of technology is through digital technologies, Network technologies and Internet technology. At the present level of development the best example of technological convergence is the application of digital technologies to systems and networks associated with services.

The convergence at this stage is underpinned by digital technologies that are commonly adopted by relevant sectors and computer technologies that now play a role in biotechnology as well as in nanotechnology. Significant changes are now occurring enabled by the commonalities of the digital technology.

Premises for technological convergence:

1. Digitalisation of the electronic related industries has provided the building block for convergence. Digitalisation when introduced in telecommunication, information technology and media it provided the platform for convergence of these industries. As a consequence the economics of supply demand and pricing have changed. Digitalisation has brought the common character of dimension that makes information easily transportable through the global network. This aspect and the fact that the transportation of information can be done almost instantaneously allow knowledge workers to be used by various countries disregarding their geographical location. In order for this to occur we need not only the digital technologies but also uniformity in education. However there might exist differences in pay between workers from different countries (Poesposoetjipto, 2004).

2. The emergence of information as a new type of commodity. Comparing to other types of commodities the economic value of the information is independent of the size and type of the carrying media.

3. Differences in the pricing model. Tariffs are now determined per minute, mile or bit. Communication devices vary widely in terms of efficiency. An example is the difference between modems.

4. Miniaturization and digitalisation within the Information Technology domain leads toward the production in related industries of commodities that are lighter and have low energy consumption. The IT industry is pulling developments in the nanotechnology industry while nanotechnology is holding the promise for improving related industries, otherwise both electronics and IT industry are facing physical limits.

Convergence in Industries: Mergers and Alliances

The ongoing process of convergence and the opening up of the telecommunication sector to full competition will be followed by the opening up of the other two sectors biotechnology and nanotechnology leading to the creation of new market structures and new roles for market players.

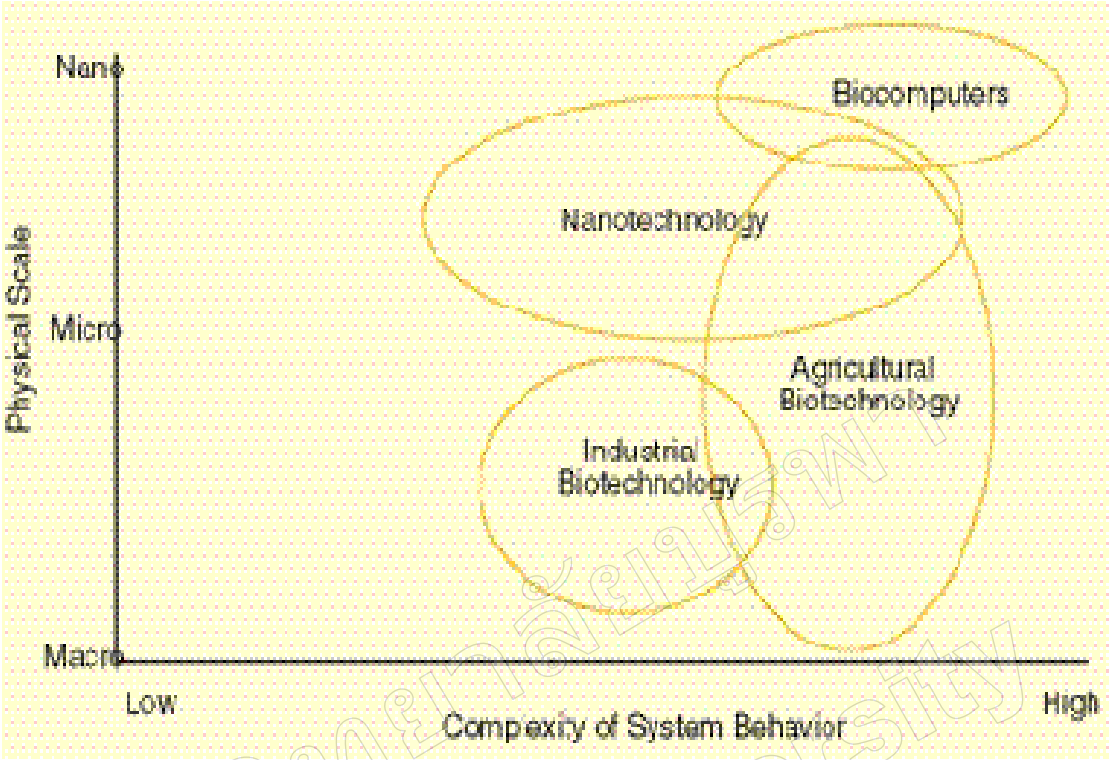
What has characterised the biotechnology industry in the 1990s was the story of alliances. In alliances two or more firs collaborate but they do not become a unified legal entity. Child (1987) points to the difference between Internet providers which function within an alliance due to bill-and-keep method of paying, while the airlines function in a different way. In the case of Internet providers the provider where the message originate keeps 100% of revenue while in the case of airlines or telephone, all contributors to the services get paid. Alliances have enabled companies to do more things and combine interests starting from clinical trials up to sharing the market. That has been particularly useful since the price for developing a drug is $500 million and many pharmaceutical/biotechnology companies are small, thus they lack the monetary resources to bring their products to market. Strategic alliances are also critical for large pharmaceutical companies, as they rely more and more on biotechnology innovation (Anon, 2001). There are alliances of many kinds such as for cross licensing of patents, cooperating in establishing a standard or lobbying for legislation. Alliances are flexible unlike the mergers and they usually last for a short period.

As mergers continue, the borders between the biotechnology industry and an array of disparate market sectors are leading to a large number of new hybrid market products. Traditionally firms produced different goods that reflect the specialisation of their employees, the configuration of their

physical capital and the experience and intellectual capital of the organisation Child (1987). Firms will buy goods from one another, sometimes customized and money will be exchanged across the boundaries. Each industry is a market for another industry. Information Technology is prone to mergers and alliances over market transactions for a number of reasons:

1. IT related goods are difficult to define count and exchange
2. They often have high fixed costs but low marginal costs (normal transactions will be difficult to apply)
3. Nondisclosure agreements offer only limited protection
4. IT is an elaborate network which implies that two firms combined have greater value than the two firms put together Child (1987).

Mergers and alliances are common in IT and in biotechnology. Many companies in biotechnology have been interacting with high-tech companies and utilising technology originally developed outside the traditional technology market. There is on the other hand lots of excitement about the rise of a specifically identifiable nanotechnology business. It is impossible to be sure what the structure of future nanotechnology industry is going to be but it is possible to study some possibilities of such an industry. Nanotechnology resembles microelectronics in the 60s and 70s and microcomputing in the 80s and is characterized by interrelated products, standards, intellectual property, stable supply chains and corporate entities not just interesting scientific and policy ideas (Gasman, 2004).



Note. (Anon, 2001)

Convergence in Markets

The phenomenon of convergence is relatively new and its implications for society and economic development are difficult to assess at this stage. One of the most significant factors is the increasing use by different sectors of the same technologies. This is occurring the most in telecommunications, media and information technology sectors. One kind of convergence is the increasing capability of existing networks to carry both telecommunications and broadcasting services. The same kind of convergence is expected to affect biotechnology and nanotechnology, the most predictable overlap being through nanomedicine and drug design. There are already companies in drug design (e.g. Starpharma), which can be considered as belonging to both fields and seeks the same market. Another example is the nanoelectronics, which belongs to semiconductors as well as to nanotechnology.

These developments are far-reaching and positive for economic and social development and should be encouraged by regulations and policies. What is needed is a wide-ranging debate on

the convergence phenomenon, which can help set a competitive market structure that will be global in nature. Convergence will ultimately lead to a more sustainable and stable market. The markets in ICT have already been changing in the last years: one indicator of convergence is the fact that some market players are exploiting opportunities provided by new platforms. The Internet providers are expanding their capabilities beyond their traditional core markets while telephone providers are entering in the area of Internet service provision and Internet voice telephony provision.

The market trends can be observed in new services and new players in a sense that the services themselves are changing towards combining the features of traditionally separate services - e.g. data enhanced television programmes - while new players such as the publishing industry for which the Internet is a crucial extension of their know-how. Information technology, nanotechnology and biotechnology they all have products that are sold in many different sectors

Convergence in Education

Convergence in education refers to the education systems. There are two important aspects in this regard:

1. The global network employing knowledge workers requires more uniformity in the education systems of different countries. An engineer trained in China has to be familiar with professional requirements for the same profession in US in order to be employed by an US company. Human capital now occupies centre stage in public policy. Industrialized countries are developing economic models based on human capital. Economic and social innovations are generated today by the creative application of knowledge.
2. Knowledge has to be more interdisciplinary.
3. New partnerships have to be established between academia and public research centres and industry.

The Impact of the Information Technology on Other Technologies

Life and business are being revolutionized by the evolution of multidisciplinary technologies such as biotechnology and nanotechnology. The enabling technology for both these technologies is information technology. Transmission and storage of information, facilitated by

computers is used in all sectors of the economy. The computers aimed initially at a small market slice but soon after they conquered the whole market: today we can barely find any business without a computer. In the light of this trend monopoly markets have been opened to competition and new regulations have been put in place by governments.

According to a study done by RAND in 2001 there are a number of Meta - trends and implications caused by the revolution of information, biology materials, devices and manufacturing (Philip, Silberglitt &Schneider, 2001):

1. Accelerating pace of technological change
2. Increasingly multidisciplinary nature of technology
3. Competition for technology development leadership
4. Continued globalisation
5. Latent lateral penetration

Convergence is commonly considered the ability of different technological platforms to perform the same kind of services or the coming together of consumer devices such as the telephone, TV computers etc. Despite the fact that this convergence is already present and unavoidable there is momentarily a struggle between computers, telecommunication and broadcasting industries for the control of future markets. There is wide spread agreement that convergence is occurring at the technological level. Digital technology now allows both traditional and new communications services to be provided over different networks. This development leads to the Information Society.

One significant factor is the *increasing use by different sectors of the same technologies.* The first development in this regard has been in information technology with the increasing capability of existing networks capable to carry both telecommunication and broadcasting services. The phenomenon of convergence is relatively new and its implications on economy and society in general are not known. There is agreement however that development in digital electronics and software are causing a new approach to the delivery and consumption of information services

The Fusion of Biotechnology and Nanotechnology

The fusion of nano and biotechnologies is now creating multidisciplinary research fields concerned with bio-engineering, electronic engineering, and photonic engineering at the nanometer, molecular, and cellular levels. This fusion of technologies allows one to envision, for example, a miniature biochip performing many of the functions of a hospital. Optimal medical treatments for individuals can be devised by analyzing and manipulating cellular biomolecules.

Hence, ultra-high-density integrated circuits can be fabricated from nano-wired transistors by biochemical techniques such as DNA hybridization. The bio-nanotechnology research projects can be classified into four main subjects as follows (Ikezawa, 2003):

1) nanoscale materials engineering,

2) materials for tissue engineering,

3) materials for drug delivery, and

4) nanoscale characterization.

Technological advances in each of these areas are rapid and exciting.

Similarities between nanotechnology, biotechnology and information technology

Studying biotechnology can provide valuable lessons to nanotechnology. One early indication of the similarities to nanotechnology is the universal lack of a consensus for a definition. Then all these industries are based on small things and show many similarities from a science perspective. Also all these three technologies require a large allocation of funds for research and development. They all need a complementary industry to form around the main technology.

Biotechnology, Information Technology and Nanotechnology are enabling technologies with a possible impact over many areas of life and industry. Some segments of these are developing faster and are attracting the development of other segments. If it is for nanotechnology to follow in the path of information technology and biotechnology a new hybrid industry will have to develop. At this stage nanotechnology is only improving existing technologies in materials, electronics and medicine (Picciola, 2002)

However the underlying science and technology is common to all these industries, they are all based on the study of small things. Nanotechnology and biotechnology use smaller sizes

compared to the semiconductor industry, but if we look at the history of semiconductors they too were considered the threshold of microscopic (Picciola, 2002). The commonalities between the nature of technology the nature of the industry the government influences and support are obvious. Industries that have the potential to have a major impact on the economy are usually surrounded by hype. This hype has negative connotations (over promising, under delivering) and positive impact (huge sums of venture capital and funding). Picciola identifies similarities and differences between nanotechnology, semiconductors and biotechnology.

Similarities with semiconductor industry

1. Process based science: what propelled the semiconductor industry was the ability to manufacture and assemble at a low cost.
2. Decreasing cost function: Moore's Law. There is already a trend in some current day nanoproductions: Tools for vision, manufacturing and assembly become cheaper.
3. High cost buyer, the government
4. Complementary industries: semiconductors enabled the information revolution which in turn triggered more demand for semiconductor based goods
5. Importance of tooling manufacturers
6. Private research and discovery.

There is however a big difference namely the diversity in application: The semiconductor applications are electronic based while nanotechnology is useful not only for nano electronics but also for nanomedicine, nano power generation, nano reactions, nano materials, etc.

Similarities of nanotechnology with biotechnology

1. New laws and understanding: research and development in biotechnology has enabled scientists to understand how the organic systems live and perform. Research in nanotechnology is forcing scientists to learn more about the molecular attraction, atomic interactions and quantum effects.
2. Impact on the value chain: biotechnology produced a disruption to the value chain of drug discovery, production and delivery. No longer did large firms dominate the entire value chain.

This is a difference from semiconductor industry, nano firms are playing major roles in design, specialized manufacturing, and have complementary distribution arms.

3. Venture capital's role in development: industries, which develop with this type of funding, require patience, long-term focus and an incremental approach.

4. University based discoveries: nanotechnology like biotechnology has been assisted by the funding from research conducted in universities.

Differences between nanotechnology and biotechnology

1. Biotechnology is a discovery-based science; nanotechnology is based more on innovation and process than pure discovery.

2. Uniqueness and complementary assets. Biodevelopments are easy to replicate while nanodevelopments are difficult to replicate because of the level of science, the wide range of problems and the process based innovations (Picciola, 2002).

Similarities between microelectronics nanotechnology and biotechnology are found in regard to:

1. Nature of technology. All three industries are based on the study of small things. All require a large allocation of funds for R&D. Each of these industries requires a complementary industry: semiconductors and biotechnology require the computers and nanotechnology high-resolution instrumentations such the scanning tunnelling microscope.

2. Nature of industry. All three industries are enabling technologies they have profound impact on other industries. For example semiconductors impact on communications, computing and electrical components, biotechnology on food and medicine while nanotechnology is expected to impact on medicine electronics and materials.

3. Government influences. All these industries have been touted for national defence. Also government investments have come on a variety of levels including basic research in universities and public institutions, basic research at private institutions and purchase of early high costs products. Other forms of government interventions were tax savings, small business loans and corporate grants.

4. Hype in the industry. Hype has affected all these industries and it has proven to be a vehicle to build awareness increase investment and provide free marketing for emerging technologies. Viewed negatively the hype can build distrust, lead to misalignment of expectations and deliverables and slow progress down.

5. All three semiconductors, biotechnology and nanotechnology are disruptive technologies. Each of the disruptions has required effort and exhibited an initial performance which was inferior to the technology it was set out to replace (Picciola, 2002).

Conclusions

Convergence issues encompass structural issues like the management of access markets, social issues such as the availability of new services and legal issues like copyright definition.

With respect to the impact of converging technologies, we are at a cross-road to move ahead. There are many issues to be faced on the standard of information connection. The development status of these three technologies of a nation is one and the educational infrastructure is another. Convergence has become an issue for governments. Government intervention in the convergence will affect national outcomes.

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