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The IPTS REPORT

EDITED BY THE INSTITUTE FOR PROSPECTIVE TECHNOLOGICAL STUDIES (IPTS)

AND ISSUED IN COOPERATION WITH THE EUROPEAN S&T OBSERVATORY NETWORK

5 The Promising Future of Internet Telephony

Energy Infrastructures: The Information Network of Tomorrow?

Europe and the Challenge of the Brain Drain

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EUROPEAN COMMISSION
Joint Research Centre

ENGLISH VERSION

ABOUT THE IPTS REPORT

The IPTS Report was launched in December 1995, on the request and under the auspices of Commissioner Cresson. What seemed like a daunting challenge in late 1995, now appears in retrospect as a crucial galvaniser of the IPTS' energies and skills.

The Report has published articles in numerous areas, maintaining a rough balance between them, and exploiting interdisciplinarity as far as possible. Articles are deemed prospectively relevant if they attempt to explore issues not yet on the policymaker's agenda (but projected to be there sooner or later), or underappreciated aspects of issues already on the policymaker's agenda. The long drafting and redrafting process, based on a series of interactive consultations with outside experts, guarantees quality control.

The clearest indication of the report's success is that it is being read. An initial print run of 2000 for the first issue (00) in December 1995 looked optimistic at the time, but issue 00 has since turned into a collector's item. Total readership rose to around 10,000 in 1997, with readers continuing to be drawn from a variety of backgrounds and regions world-wide, and in 1998 a shift in emphasis towards the electronic version on the Web has begun.

The laurels the publication is reaping are rendering it attractive for authors from outside the Commission. We have already published contributions by authors from such renowned institutions as the Dutch TNO, the German VDI, the Italian ENEA and the US Council of Strategic and International Studies.

Moreover, the IPTS formally collaborates on the production of the IPTS Report with a group of prestigious European institutions, with whom the IPTS has formed the European Science and Technology Observatory (ESTO), an important part of the remit of the IPTS. The IPTS Report is the most visible manifestation of this collaboration.

The Report is produced simultaneously in four languages (English, French, German and Spanish) by the IPTS; to these one could add the Italian translation volunteered by ENEA: yet another sign of the Report's increasing visibility. The fact that it is not only available in several languages, but also largely prepared and produced on the Internet World Wide Web, makes it quite an uncommon undertaking.

We shall continue to endeavour to find the best way of fulfilling the expectations of our quite diverse readership, avoiding oversimplification, as well as encyclopaedic reviews and the inaccessibility of academic journals. The key is to remind ourselves, as well as the readers, that we cannot be all things to all people, that it is important to carve out our niche and continue optimally exploring and exploiting it, hoping to illuminate topics under a new, revealing light for the benefit of the readers, in order to prepare them for managing the challenges ahead.

Preface

The opportunities and challenges created by the simultaneous establishment of the Monetary Union, development of the European Single Market, and enlargement of the Union's membership all suggest major changes for the EU in the coming ten years, perhaps among the most significant ever to happen in Europe in time of peace.

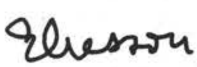
Moreover, the continued fast paced developments in information and communication technologies and life sciences, as well as the full impact of integrating environmental concerns in all aspects of policy making create major opportunities for mankind, but at the same time, pose serious societal questions which will also condition Europe's future.

Indeed, by 2010, we will see a substantially different economic and geo-political environment, where the way we work and live will be profoundly affected. In this context, it is especially important to help develop a European Union which reinforces prosperity and employment, whilst responding to the pressures from competitors from abroad operating in very different environments. The opportunities offered by these sweeping changes will be especially important for Europe, where they will represent a rather unique, one-time, chance: this is especially obvious in the case of the creation of the EURO.

For that reason, I have asked the Institute for Prospective Technological Studies of the Joint Research Centre to analyse the policy implications arising from these forces, which are driving Europe's competitiveness, employment and technology policy.

The purpose of this initiative, known as the Futures project, is to analyse the impact that such challenges will have for policy decisions. The Futures project, which started in April 1998, is engaging more than 150 experts and policy-makers to work in an interactive process based on expert panels and policy workshops, supported by background research, and in which all concerned Commission services have been associated.

Without question, the EU will be very different in the year 2010 from what it is now. I look forward to the results which we will get from the Futures project to help make Europe not only different, but most importantly a much better place to live and work in.



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The triple-helix model of interactions between academia, government and business in the promotion of technology innovation could be a useful model to help understand S/T policy issues.

EDITORIAL

Dimitris Kyriakou with G. Di Pietro and S. Gómez y Paloma

The Euro-Mediterranean partnership announced during the Interministerial Conference at Barcelona in November 1995 comprises a series of policy statements and agreements on economic, technical and financial cooperation designed to form the groundwork for a free-trade zone between the European Union (EU) and the non-EU, or Mediterranean Partner Countries (MPCs) to be established by 2010.

What is the role of S/T in making this happen, and making it last? There are at least two channels in which the S/T contribution can be critical; they both operate through income growth. There are significant demographic and migration pressures originating in MPCs which are exacerbated by insufficient income growth levels, and these are projected to continue.

Two of the ways in which a country can raise its income are trade and technological progress. The creation of the Euro-Mediterranean free trade area will not only explore the first channel, it will also promote the second. The setting up of the Euro-Mediterranean free trade area will likely increase technology diffusion towards MPCs. But this is not the end of the story...

In the context of free trade MPCs may increase their income by specialising in types of production where they have a comparative advantage; however, this situation could lead Southern EU countries and MPCs to compete in the same economic activities. Whereas above we saw how free trade can enable the income enhancing role of technology (through technology diffusion), technology in its turn can safeguard gains from trade and alleviate tensions emanating from increased competition by promoting symbiotic relationships.

Technology may enable two kinds of symbiotic relationships between Southern EU countries and MPCs. First, the EU and MPCs may target different segments of a market by occupying different technological niches. Second, an efficient division of labour may be achieved between EU capital intensive activities and MPCs' labour intensive activities through a process of vertical integration. For instance, in the last five years the significant enhancement in trade between MPCs and southern regions of Italy in traditional industries may be attributed to the increased cooperation between SMEs across the Mediterranean basin.

The Promising Future of Internet Telephony

Ioannis Maghiros, *IPTS*

5 Information and Communication Technology

Issue: As a result mainly of the liberalization of international telecommunication services and the rapidly evolving technological environment, the migration from traditional circuit-switched networks towards shared packet transport networks has enabled a mix of new applications to emerge. Among these is Internet telephony (ITel) or voice over IP (VoIP), the technology that enables voice calls to be routed over public or private data networks.

Relevance: An increasing number of major players from a variety of different backgrounds are coming together to provide a new set of Internet-based multimedia-content services, based on Internet telephony technology. This is placing increasing pressure on the policy-maker to regulate, even before the ITel technology becomes commercially mature.

Introduction

ITel is a technology that allows voice to be transmitted worldwide over the Internet at very low cost. This is accomplished by digitizing and cutting-up voice calls into digital packets, which are then compressed and transmitted independently over the Internet to their destination where they are reassembled into speech. Initially it allowed only PC to PC connections through complex and low speed, low quality technology. Technological advances have recently enabled the technology to be used for PC-to-telephone and even normal telephone-to-telephone connections, thus allowing a wider variety of applications to be developed, including Internet faxing, a system intrinsically better suited to packet-switched networks.

Whatever the consequences of this technology, i.e. whether it comes to replace traditional long distance of telephony service carriers or if it enhances the utility of the computer interface to provide novel added-value services, its rapid development is due to the fact that it offers cost savings relative to standard telephony pricing schemes. This economic advantage stems from the more efficient use it makes of existing long-distance bandwidth (least cost routing and better compression techniques at the expense of sound quality), as well as by avoiding inflated cross-border tariffs[1] (bearing in mind that currently access fees for long distance traffic do not apply to the Internet). It could of course be argued that the currently achieved price-performance efficiency would decrease as future Internet access changes are implemented internationally.

ITel technology allows voice transmission via packetized data communication across the Internet. Originally only possible from PC to PC technical developments are expanding the quality of the service and the range of possibilities

Technological Developments

ITel technology applications go beyond simply replacing phone-to-phone communications (voice, fax). The range of possible applications includes unified Web-messaging mostly over

Although at present the main attraction of ITel is price, its wide range of multimedia applications means in the long run it will be able to offer enhanced functionality to users

corporate Intranets (voice, text, video, shared workspace, etc.), Internet call waiting and Web-enabled call centres. In the long-run ITel may come to include all computer-mediated human communications in order to offer enhanced functionality for the end-user. However, if this is to be achieved, the Internet itself needs to become more efficient and reliable. Some of the more important ITel-related technological issues for which solutions are required include:

- **Internet bandwidth**: The current implementation of ITel technology requires less bandwidth than most other Internet applications (e.g. Web browsers). However, it is predicted that emerging applications will end-up using a greater share of available bandwidth in order to deliver better quality multimedia content.
- **Access device technology**: Utilizing the standard telephone, instead of a PC, is becoming possible thanks to set-top boxes costing a fraction of the price of a PC (Box 1). The use of the telephone as an entry-level device for Internet applications[2] (e.g. e-commerce, advertising) may have significant future impacts. Conversely, an enhanced capability PC could act as 'Call Manager', providing end-user functionality, such as teleconferencing and tele-working, mostly needed in the business environment.

Box 1. Access Devices, Enhanced Applications and Industry Protocols

- A French firm has developed a low cost software/hardware system (the 'Aplio' box) that may be connected directly to the normal telephone line allowing cost-effective communicate voice via the Internet. The user dials the number of the person he wishes to talk to (who must also own an Aplio-box) and as soon as the phone on the other side rings, he presses a button and hangs the handset. The Aplio-box then re-instates the communication path by dialling through the public Internet, thus providing ITel cost-savings through the standard telephone handset.
- The convergence of voice and data already appear to have become a commercial success, especially in the area of "Customer Interaction Networks" where services such as scheduling of response times and segmenting of customers into priority groups is of vital importance. With early applications appearing in the financial, customer support and the medical services industry, these systems allow each call and/or e-mail message that enters the system to be identified and matched up according to customer records stored in a network database. Immediately specialized staff is 'priority assigned' to the customer support task.
- Data networking company Cisco has developed a "tag-switching" protocol with which the first packet carries sufficient information to clear the path for subsequent packets. Ericsson has developed an ITel system which offers phone-to-phone, fax-to-fax and PC-to-phone services over an IP network for service providers to use, which includes a Web based operations and management facility. Moreover, Cisco and hardware manufacturer Hewlett Packard are developing a billing system that would allow Internet Service Providers extract accounting information from an IP environment, similar to the one telephone operators exploit, in order to bill clients accordingly.

- **Standards (and bridging capabilities)**: Such as the public telephone network PSTN/IP Gateway Interoperability standard, which allows IP-encoded voice messages to enter the public telephone system but could be enhanced to support Data calls and fax, and priority-handling standards, such as the Resource reSerVation Protocol (RSVP), which enables an application to request a certain amount of bandwidth with a maximum acceptable delay[3] are also critical.
- **Quality of Service**: QoS, mainly describing the audio quality of the service, is a factor that allows different market segments to develop in parallel depending on the pricing models implemented. Individuals may accept some loss of audio quality for calls that are virtually free, whereas a company might be willing to pay extra for improved audio quality as well as multimedia value-added services. Minimum acceptable levels of audio quality at a low price may accelerate the diffusion of Internet-based voice systems.
- **Security**: Software problems encountered when mixing commercially available encryption products with voice compression, together with the fact that voice traffic is sensitive to latency, means there are currently problems with the security of voice traffic over IP networks. Hardware-based security is currently available but at a cost that would undermine its economic attractiveness. In addition U.S. export restrictions that limit the use of strong encryption software may prove to be a legal hurdle for international ITel implementations.

Market Developments

The number of ITel users globally is expected to grow to 5m by the year 2001, a very lucrative market segment considering the added-value services on offer but of small dimensions compared to the existing 300 million Internet users or the 500 million mobile telephony users market. Moreover current figures for ITel revenues, estimated at $300 million (US), do not represent a threat to standard telephony operators (international call market valued at nearly $70 billion – see ref.7). Nevertheless, a recently released study from Tarifica, (see ref. 6), predicts that ITel may represent as much as 43% of fixed and mobile international traffic by 2003 despite quality and interoperability issues. In addition the number of new entrants in the market (Box 2 – ITel Market Developments) also confirms the vigour of ITel.

Consumer ITel applications (phone, fax) are currently more widely publicized, but corporate demand for ITel will be the new market mover since many enterprises own dedicated data lines on to which ITel of standard quality may blossom. Other more end-user added-value applications are dependent on the evolution of the Internet market as a whole and as such they will only come later and at different stages of the Internet evolution. Incumbent operators are left with the choice between either missing out on a new market or moving into the ITel market and trying to make the best of their Intranets, on which they guarantee QoS, for new added-value services, albeit under the threat of lower profitability for telephony services. However this scenario is not likely until the international call market is no longer so profitable, and related legislation and interoperability standards are better defined.

In this setting, longer-term profits will be derived from the investment in IP infrastructure for those engaging in added-value services. Nevertheless, there is growing concern by all actors involved (private and public), over the evolution of the existing regulatory environment as a result of the growth of ITel as a substitute of circuit switched transmission. In addition, it is

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Realization of the potential of ITel will depend to some extent on solutions being found for access-device availability, security, quality of service and bandwidth issues, which affect the Internet as a whole

The number of users is expected to grow substantially over the coming years. Perhaps the most important drivers will be corporate users seeking to get the most out of their existing Intranets

Box 2. ITel Market Developments

In 1997 commercial development of ITel (initially dominated by relatively unknown start-ups like VocalTec, NetSpeak and eNet) saw significant market interest from a number of strong Telecommunications Industry actors, such as (i) data-networking companies (Cisco, Bay Networks); (ii) telecoms equipment vendors (Lucent, Nortel, Siemens), as well as (iii) the more traditional PTT operators (Telecom Finland - Sonera, Deutche Telecom). Today in the U.S.A. almost 30 companies offer VoIP and fax services at prices that are up to 75% cheaper than standard prices. Examples of this fervent activity include:

- IBM has agreed to offer IDT's Net2Phone product to their ISP customers, charging a rate of between 10 and 20 cents per minute to calls to most of Western Europe for its PC-to-phone service.
- AT&T recently announced a new service called Connect 'N Save, offering two stage dialling and using AT&T's IP Network in the US. AT&Ts revamped Chat'N Talk program is on offer to Lycos chat group participants offering additional voice communication capabilities.
- Deutsche Telecom, offers a service (phone-to-phone, PC-based ITel) to almost 100 countries starting from its UK based subsidiary T-Net Call and using its own proprietary links.
- France Telecom has installed an inter-office phone connection (a phone-to-phone system over frame relay) between its NY, Chicago and San Francisco sites; it has also bought a holding in the American gateway design company eFUSION.
- Shell Sweden is offering its customers the possibility of making calls abroad and to cellular phones using ITel in co-operation with the Swedish telecom company Glocalnet.
- Siemens is trialing a carrier grade ITel solution based on Netspeak advanced ITel software.
- Chiyoda Sangyo of Japan is offering a commercial service of very good quality, which is totally transparent to the end user and costs 75 Yen per 3 minutes (compared with an average 450 Yen per 3 minutes offered by KDD of Japan and a call-back service also on offer from Chiyoda for an average 150-200 Yen per 3 minutes). [Source: USA Today, 10 Feb. '98; and ref. 7].

The growth of ITel will have an impact on the profitability of standard telephony, pushing operators into services with greater added value

clear that advanced uses of ITel bear little similarity to the basic telephony service. In the end, there is an increasing demand on the policy-maker to regulate even before the ITel technology proves to be commercially mature (Box 3 – Recent Legislative ITel related Developments world-wide).

In the near future, if there are no changes to the current regulatory status of ITel, the increasing pressure on the existing pricing model from new market entrants is likely to draw incumbent telecoms providers into the ITel market. This could well result in market fragmentation and an erosion of the competitive advantage small players have in supplying basic ITel services. Indeed, it is likely to cease to be cost-effective for many of them, and only those service providers with well-defined QoS levels and who offer supporting services will be able to compete by providing higher level ITel services. Therefore basic ITel (no extra functions at the end node) becomes part of the transmission media context while advanced end node functionality becomes a service, independent from the communications infrastructure.

Box 3. Recent Legislative ITel-Related Developments Worldwide

In the **U.S.A.** in 1996, a group of long-distance telephone service providers petitioned the Federal Communications Commission (FCC) to ban phone calls over the Internet, despite the fact that the general stand is for a "regulation-free Internet" on both sides of the Atlantic. That petition was dropped but a similar one resurfaced in U.S. Congress in 1998. On a more positive note, in **Japan** non-Internet related international telephony was de-regulated as of December 1997, while ITel has been de-regulated since August 1997. In January 1998 the **European Commission** published a communication on the 'Status of voice communications on Internet under Community Law' and in particular under Directive 90/388/EEC, which covers the issue of possible contributions to universal service schemes and the issue of licensing procedures and obligations applicable to ITel providers. According to it, ITel providers are excluded from the Universal Access obligation because ITel is not a "voice communication" service - as it neither uses the Public network (mostly dedicated lines), nor does it enable any-to-any user connection (only Internet subscribers are enabled). Finally, being packet-switched it is not considered to be real time communication.

In this environment, the evolution of regulation has to address the questions of multimedia services integration and infrastructure, network bandwidth and network interconnection, and interoperability[4]. The scope of such an intervention should go beyond investigating different Internet access pricing models, which permit service guarantees for multiple qualities of service, since what is at stake is a new class of added-value services favourable to consumers. Universal service obligations of various flavours should also be studied for both low and high-end ITel applications. A pivotal question is then what the public interest consideration of the ITel service is and what responsibilities the providers of these services have towards the public.

Universal Access

The Internet is currently seen as a resource for basic information access as well as means of communication. Universal access to the Internet, a prerequisite to universal service, means that publicly available information can be made available at very low cost. In the past, government-owned monopolies in the communications sector contributed to a Universal Service Fund (USF) so as to allow the provision of uniform services enabling communication, independent of the true cost of supply. Today, infrastructure development should be the outcome of market competition, that is providing high quality services and equipment at low cost. Allowing the competitive forces of the market to decide on the range, price and quality of services offered over the existing infrastructure does not conflict with the realization of Universal Service targets[5].

The importance of universal access for the so-called information "have-nots", that is to say the poorest and less educated part of society, lies in the fact that it may empower them to improve their own lives. As an example, ITel, which lowers the cost of using and maintaining a phone line, could help introduce the "phoneless", one of the most disadvantaged groups, to the advantages of a networked society[6]. Enabling private Internet Service Providers capture this part of the market,

Once competition from small ITel operators goads incumbent telecoms companies into the market the future for the players who do not offer QoS guarantees will become difficult

Universal service obligations will have to be re-evaluated in view of market developments if ITel comes to take a significant share of the voice market by providing incentives involving or not public subsidies could also be promoted. In this case, providers will mainly compete for a bigger share of the market where profits will remain very low but where it is still worthwhile to compete.

Although content and access to content are different issues, convergence in the telecommunications, computing and media industries indicates that broader objectives for Universal Services targets should be established and thus appropriate financial resources made available. In this area decision-makers could consider the following:

(a) the cost of access devices (possible advertiser-support, virtually free or donated devices)
(b) the level of access to the range of new services (free access in return for tax and other benefits (e.g. brand name use), access to content is not included)
(c) the availability of local access points (usually public) as service providers (possibly enabling access to teleworking and/or training courses offered by public services for their staff, University Intranets, government resources)
(d) real user needs (socially important, carefully localized services in view of the differences between the European Regions)
(e) the accessibility of essential information to all, either free or at affordable prices
(f) the practical desire to participate in the 'Information Society' (to fight social exclusion).

ITel looks to be the herald of a jump from fixed circuit to packet switching for all telecoms and the overall effect is likely to be reduced profits from the physical medium and a drive for cheaper hardware and enhanced service software in the fight for customers

Conclusions

Just two years ago, it was widely believed that since the common telephone system works quite well as it is, any novel technology that could substitute it, would have a hard time on the market. ITel was a technology with no commercial future to be used by 'Netizens' only. Since then ITel has improved to the point where it is offering a rapidly improving voice quality product and the market segment it has created is eating into the telecommunication industry's traditional revenue base[7]. There are a few technological problems into which research still needs to be done if added-value functionality is to be provided to ITel users, but most of the solutions are related to the general evolution of Internet technology as a whole (bandwidth, standards, market size, lack of applications, etc.). Voice, video, audio and data will then be exchanged, depending on the access device, bandwidth, quality required by the software application as well as pricing model applied, regardless of the facilities used –i.e. the physical network the user will be communicating on.

Profit opportunities from rate arbitrage are currently driving ITel development. De-regulation and more competition will push ITel development in the closed corporate Intranet environment where Internet-related problems are solved with less difficulty anyway. Moreover, telecoms operators may have to adopt this technology widely, in spite of quality and reliability problems, and actively engage in offering added-value Internet services over their own IP infrastructure, thus making competition move away from the provision of physical media (towards virtually-free bandwidth). If the voice market segment decreases, besides becoming a diminishing revenue service, then profits could be maintained through equipment investment, software upgrade costs and through offering higher quality, reliability and security products to business users.

The most obvious implication of this market evolution scenario will be a simplified technology, low threshold service for the "have-nots" and an enhanced functionality service with a number of added quality layers for business users. In this case, similar to the current conventional telephony environment, existing legislation which differentiates 'telephony operators', is open to question as it imposes obligations that seem to be an obstacle to market restructuring in tune with the underlying technological trends. The application of competition rules, in conjunction with a new set of Universal Service Obligations would play a crucial role in this evolution scenario. On the one hand recourse to competition policy will ensure services such as directory services or payphones are provided without unfair practices and on the other a redefinition of cost-orientation and separate accounting for services and networks would lead to further integration of "medium and message".

If voice telephony makes the jump from running on circuit-switched to packet-switched networks, as is widely believed, it is almost certain that the traditional telephony environment will change to the benefit of the consumer. In such an environment, regulation should move in tandem with competition-driven innovation.

Keywords

Internet Telephony, VoIP, ITel, technology trends, policy implications, Universal Service Fund, Universal Access

Notes

1- Conventional telephony charges are time and distance dependent and settlement charges for long-distance calling artificially inflate prices paid by the end-user.

2- The use of touch-tone selection to navigate through Internet based services is a rapidly evolving human to computer voice communication application; a first implementation instance of this technology is the VoxML (Voice Markup Language) programming language by Motorola soon to become a market standard.

3- The time delay for a round-trip between two well-managed IP backbone networks is of the 50 to 60 ms range, while the average round trip over the Atlantic could be in the 400 to 800 ms range, with a human perceiving audio delays greater than 250ms.

4- Public consultation on the Commission's Green paper on convergence of telecommunications, media and information technology sectors initiated in December 1997.

5- Basic Internet access (low speed) is part of the Universal Service to be guaranteed by the Member States under Community Law (98/10/EEC).

6- As an example, currently the number one user of ITel Debit cards in the U.S.A., are the various immigrant communities, who would not have been able to afford standard telephone access charges.

7- According to the International Telecommunications Union, ITel could eliminate the profits of U.S. long-distance carriers by taking just 6 percent of U.S. telephone traffic. (ITU, Sep 97).

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Energy Infrastructures: The Information Network of Tomorrow?

Gérard Carat, *IPTS*

Issue: In 1997 a new technology capable of transmitting data over the mains electricity grid at speeds of 1 Megabit per second, was unveiled. The ubiquity of electricity cables makes this technology easy to disseminate and could reduce the dominance of incumbent telecoms operators on future broadband services.

Relevance: At a time when telecoms liberalization has not proved successful at providing genuine local loop competition, the use of the grid as a data network could position power utilities as key protagonists in tomorrow's Information Society. The likelihood of flat-rate charging for this permanently-connected data service could add pressure on telecoms operators to modify the way they bill Internet services, generally invoiced on a per-unit-time basis. It could also act as a catalyst for the uptake of Internet telephony.

Powerline Communication

PowerLine Communication (PLC) is the generic name for data transmission over the low voltage segment of the electrical grid from the electricity substation to the customer's home or premises. Over the years engineers have worked on the possibility of sending a reliable signal over electrical wires in spite of electrical noise and electromagnetic interference[1]. A major development in this field took place in October 1997, when the UK electricity company Norweb, in collaboration with Canadian telecommunications manufacturer Nortel, announced they were able to transmit data signals at speeds of 1 Megabit per second over the low voltage segment of the electricity grid with a proprietary technology called "Digital Powerline" or DPL. The interest in the technology shown by an increasing number of international electricity operators has led the partners to create a joint-venture, NOR.WEB which has signed agreements with a dozen power utilities to test the technology. The potential market under these agreements could cover around 40 million homes in seven countries in Europe and Asia.

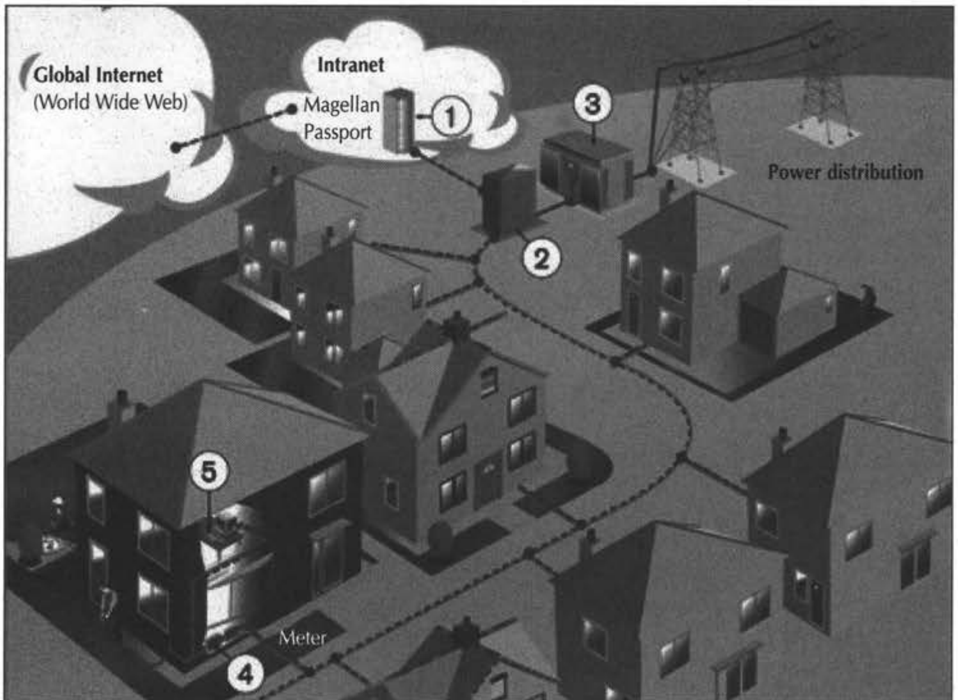
Advantages of PLC technology

- As PLC is being positioned as an IP-type service it will use packet routers rather than the circuit switching typical of traditional telecoms providers, thus keeping IT equipment costs down.
- As electricity is being supplied via a permanent connection, the data service offered over the electrical infrastructure is also permanently connected (no need to dial up the

PowerLine Communication (PLC) is the generic name for data transmission over the low voltage segment of the electrical grid going from the electricity substation to customers' premises

Under joint-venture agreements this technology could be brought to around 40 million homes in Europe and Asia

Figure 1. How DPL Works



Digital Powerline (Fig. 1) uses existing low-voltage underground electricity distribution network as a LAN infrastructure. One or more Main stations (1) are used to connect the Base stations (2) to a core data network where line of sight radio, copper cable and fibre are possible options for this 'backhaul'. Connection to the service provider network and the public Internet is achieved via the core data network. Data signals from a DPL 1000 Base station are usually injected at the final substation (3), where high voltages are transformed to the low-voltage power supply for the customer premises. The DPL service is separated from the electricity supply at a connection point between the main service fuse and the meter (4). The customer's PC or other compatible equipment is then connected to the DPL service using the DPL 1000 Communication Module (5).

Source: Nortel

connection), making it ideal for the increasing number of online services. Power utilities will thus be able to market a basic Internet connection service at a flat-rate monthly subscription, like some cable operators. Paying a standard fee, irrespective of usage levels, will be a key attraction to customers.

- By giving electricity customers access to the Internet through their existing electrical supply system, the technology is available to virtually anyone, giving the technology potential mass market scale, without having to invest in digging cable links to homes.
- A number of technologies already exist for turning existing electrical cables into LAN wiring[2]. What makes PLC different is the high data rate achievable and the fact that it is also designed to work outside the home or building. Thus sophisticated domestic-automation systems could be implemented, allowing remote access and control of household appliances, burglar alarms, etc.
- PLC could also enable utilities to offer added-value sector-oriented services such as energy management (by linking up 'smart' meters, programmable controllers and 'Intelligent'

demand/supply management devices so the utility could implement innovative tariffs to reward the sensible use of energy), remote monitoring (the permanent connection offered by PLC could be optimized to provide real-time information or status indicators in support of certain security applications for alarm/monitoring systems), and distribution automation (automatic remote meter reading would improve monitoring and assist utilities in the control of power distribution peaks). Some utilities have recently started some of these applications[3].

Comparison of local access technologies

This section briefly lists the characteristics of some of the fastest local access technologies/platforms planned or on the market to help assess the competitive advantages of PLC.

1. Fibre optic deployment to the home is obviously the most efficient and "future-proof" way of providing high bandwidth, but, although Japan has opted for this solution, its deployment on a national basis implying changing millions of copper cables is prohibitively expensive.
2. Wireless Local Loop (WLL) can be split between low bandwidth for telephony and broadband. In the case of the latter, Local Multipoint Distribution/Communication Service (LMDS/LMCS), is a promising example of wireless, two-way broadband technology, for which the United States and Canada have allocated spectrum. In the 4th quarter of 1998, the German government will award blocks of broadband WLL frequencies covering the whole of Germany. In other countries, the success of this technology as a credible competitive broadband access will mostly rely on its ability to secure nationwide spectrum allocation.
3. Universal Mobile Telecommunications System (UMTS) will undoubtedly reshape the market and modify the frontier between fixed and wireless communications. Most EU Member States have at least 4 mobile operators eager to compete on this new wireless transmission platform. Its commercial introduction is due in 2002, and bandwidths of up to 2MB/s in some areas are likely to be introduced later, which leaves a window of opportunity for the (early) introduction of alternative broadband infrastructures.
4. xDSL is a generic abbreviation for a number of types of Digital Subscriber Line technology which provide voice and high-speed data services, of up to 6 MB/s over a single pair of copper telephone wires. The advantage of this modem technology lies in using the existing copper-wire telephone infrastructure, allowing telecoms operators to stay ahead of the competing access products which require huge infrastructure investments in order to give widespread access. According to Ovum, "xDSL lines (worldwide) are predicted to grow from 7 million (in 1997) to 49 million by 2003"[4]. However, the cost and pricing of DSL technology remains high in Europe[5], although expected to decrease, and DSL's performance will vary greatly depending on the state of the copper network and the distance between subscribers and local/regional exchanges. Like PLC, ADSL has a permanent connection up to the switch.
5. Cable Modems: Cable TV networks offer a dedicated service over a shared media. While cable networks have high downstream bandwidth capabilities (up to 30 Mbps), that bandwidth is shared among all users on a line meaning performance is in inverse proportion to the number of simultaneous users in the neighbourhood. The main technological hurdle is that the upstream traffic is often slow as cable TV infrastructures were historically built for a broadcast service. Many of the older cable networks are therefore not

PLC offers electricity utilities the opportunity to offer their customers more sophisticated energy-related services and flat-rate broadband connections well-suited to Internet-type services

A variety of access technologies and platforms exist, such as fibre-optic links to homes, cable modems and satellite. However, in general these platforms require very large investments

Current broadband technologies do not have the required infrastructure or spectrum to reach a mass market in a short time-frame

PLC suffers from a number of inherent limitations, such as vulnerability to electromagnetic interference and the fact that bandwidth must be shared between neighbouring users

The existence of ready-made infrastructure, however, makes PLC the most investment-efficient way of breaking the incumbents' monopoly over the local loop and catalysing the market to move towards fixed-rate charging

capable of offering a return channel and will need upgrading before they can offer broadband interactive services. While the number of homes that can support two-way cable modem transmissions is growing steadily, progress is relatively slow[6], which leaves a margin for action for incumbent telecoms operators to enhance and deploy DSL, but also leaves a market opportunity for electricity utilities that are considering offering PLC.

6. Broadband Satellite constellations[7] such as Teledesic are ambitious projects but capital intensive and will take years before possible market uptake (Teledesic is estimated to cost $9 billion, is a proprietary technology and will not be operational before 2003). This technology also incurs inherent risks[8] and today's turmoil in world financial markets has made investors shun all but the most creditworthy borrowers, which could make it more difficult for satellite communications companies to raise the money they need to fulfil their plans in coming years. On the other hand, satellite consortia like Intelsat and Eutelsat already offer high-speed satellite-based Internet access (e.g. of up to 2 Mbps downlink per user with Eutelsat multimedi@ platform).

The categories mentioned above are only indicative, since the frontiers between technologies are shifting. For instance CATV networks can be controlled by electricity utilities themselves, in which case they will have fewer incentives to deploy PLC-based services; and when some countries like the Netherlands have over 90% cable penetration, the rationale to deploy PLC is reduced.

Also significant is the fact that the broadband technologies currently on the market can yield comparable or higher throughput than PLC but generally do not have a fully deployed infrastructure with which they can reach a mass market in such a short timeframe. Those that can are already offered by incumbent operators (DSL) or, by satellite consortia in which they are signatories (eg. Eutelsat)[9], which leaves a window of opportunity for PLC as a competitive local-loop technology.

Where does PLC fit in?

In spite of its promising features, PLC still has a number of inherent limitations to overcome, such as its susceptibility to electromagnetic interference (which particularly affects aerial cables), resulting in unacceptably high levels of high frequency (HF) interference[10]. Also, its topology has similarities to that of cable networks in the sense that, as a shared medium, the advertised optimal bandwidth could be reduced as the number of users simultaneously connected to the same electrical substation increases.

These limitations will not allow PLC to become a revolutionary technology overnight, especially since incumbent operators are beginning to introduce xDSL and Internet via satellite.

However, in our view, there are 2 reasons why PLC could be developed:

1. The business case for PLC is its ability to acquire a critical mass given the size of its infrastructure, strong (mass) marketing power associated with the ubiquity of its network, and, arguably, its competitive pricing[11]. Policy agendas aiming at breaking incumbent operators' virtual monopoly over the local loop (see below) could look favourably on the deployment of PLC technology as a potential competitor to ADSL insofar as nationwide electricity infrastructure is already fully deployed, which is not the case for cable[12], let alone truly interactive cable services[13].

2. European Telecoms operators are still reluctant to modify their current pricing and to introduce a flat fee for local traffic, a change which is seen as one of the key enablers of internet take off[14]. In addition, xDSL is being deployed very slowly in Europe. If successful, PLC's permanent connection technology could act as a catalyst for the rest of the market to start invoicing on a lower-price, fixed rate basis, reinforcing a tendency initiated by Internet via cable TV.

Policy aspects

A number of policy aspects arise in relation to PLC technology and its uptake. These related to IP telephony uptake, the dominance of incumbents over the local loop, the possible need to consolidate existing regulatory frameworks and the effect of utilities 'bundling' services to offer consumers services outside of their traditional areas.

IP telephony uptake: Given that worldwide data traffic is growing at roughly 30% a year while voice is expanding at just 3%, and that data traffic already exceeds voice traffic, the logical direction in the future is toward carrying voice on networks optimized for data rather than the other way round. If the PLC technology (initially used for data) proves successful, it may also accelerate the take up of IP telephony and hence accelerate the need to adapt the legislation on the matter, *inter alia* the European Commission's stance on IP telephony[15].

End of the dominance of incumbents over the local loop

Since the liberalization of the telecoms sector, little progress has been made by alternative local loop operators, and market shares of the incumbents in the fixed local loop in all Member States remain above 90% (given that the main investors in alternative fixed infrastructure remain incumbent operators investing abroad). This concern has been recently voiced by DGIV[16]. In this respect, the PLC technology could be seen by EU regulators as a catalyst for genuine competition on the local loop, especially for broadband services which will shape tomorrow's information economy.

In the US the relevant authorities are also in the process of determining whether advanced capabilities are "being deployed to all Americans in a reasonable and timely fashion", or whether the regulators must "take immediate action to accelerate deployment of such capability by removing barriers to infrastructure investment and by promoting competition in the telecommunications market"[17].

The current debate on sector specific vs. general competition rules may also evolve. Many incumbent operators still argue that they are unfairly targeted through the concept of significant market power, arguing that the regulatory framework should address bottlenecks rather than individual players. EU telecoms liberalization has so far not fully succeeded in changing the specific characteristics of a sector where large investment costs in duplicating networks, particularly at the level of local access, will continue to create bottlenecks which market forces or the application of competition rules cannot always resolve. The level of investment required entails the need for a degree of certainty as to the regulatory treatment which general rules cannot always provide. Availability of a ubiquitous broadband competitive infrastructure enabled by PLC may contribute to alleviate the issue.

Worldwide, data traffic is growing at 30% a year, whereas voice is growing at only 3%

Alternative operators have yet to make significant inroads into the local loop end of telecommunications, despite liberalization of the sector

Allowing regulated utilities to compete in other differently regulated markets creates a risk of distorted competition if frameworks are not consolidated

If its technical limitations are overcome, PLC has the potential to enable new data transmission services which will ultimately benefit customers and give extra impetus to the information society

Consolidation of distinct regulatory frameworks: In the UK the deregulation of the electricity industry has promoted mergers between utilities so as to offer a wider range of services. Previously each market, electricity, gas, water, telecommunications, had its own separate regulator but, if no immediate changes are predicted for the immediate future, the regulatory framework will have to be consolidated accordingly. The Green Paper on multimedia convergence[18] confronts the complex issue of adapting regulatory frameworks to converging markets. A concrete example in the energy sector is the disagreements over the so-called 'dual fuel' contracts currently being offered by the UK Regional Electricity Companies (RECs), where a REC is able to offer gas as well as electricity to customers in its region. This has antagonized the gas industry, as the gas market is opening up to competition more quickly than the electricity market, and before the electricity market is open, monopoly RECs will be the only companies able to offer both electricity and gas to their customers, thus creating market distortions.

'Bundling': This means associating supply of one service to the supply of other services, may be economically optimal, but it may also have anti-competitive effects. For instance power distributors could be tempted to leverage their dominant position in electricity delivery to cross-subsidize other services, a typical example would be to use price rebates for combined consumption of telecommunications and electrical services from the same provider.

Conclusions

For many years power utilities have used the high and medium voltage network in order to transmit data for their own operations e.g. remote dike opening, grid supervision and fault identification, but this was limited to low speed data transfer for internal purposes.

More recently, some utilities like Energis in the UK have installed fibre-optic cables along their electricity pylons and rights-of-way so as to offer competitive long-distance telecoms services. PLC is a useful local loop complement to these long distance services. Power utilities initially positioned as competitive long distance telecoms operators could therefore use PLC to transform themselves into full-fledged telecoms operator offering local and long distance telephony, thus taking on the dimensions of a genuine alternative operator. The low profitability of local loop infrastructure could also be compensated for by more profitable in-house long distance operations and the energy-related value added services.

By helping power utilities provide a full range of information services, PLC technology will assist in customer retention as the power distribution industry deregulates over the next decade.

Ironically, from a technical point of view it would be difficult to imagine a worse infrastructure to transmit data over, given the essential incompatibility between electrical bursty noise and data. Yet the competitive context in which power utilities have been operating in the UK has encouraged them to explore this avenue, illustrating the way in which competition can be a driver for innovation.

If technical limitations are overcome early enough, PLC could influence the future shape of the market, especially since this 1Mb/s permanent connection is well suited to the worldwide growth of bandwidth-hungry applications over the Internet. Helped by a strong marketing presence associated with a ubiquitous network, power utilities may dramatically increase the pace at which alternative local loop carriers take market share from incumbent telecommunications operators.

PLC could therefore be taken as a competition enabler in a sector in which to date local loop competition has been difficult. The opening up of this area to competition will clearly benefit the consumer as likely outcomes include reduced phone (and data) bills, pressure for flat rate billing and ultimately a further catalyst for the information society.

Keywords

competitive broadband infrastructure, telecommunications, multimedia, electricity utilities, local loop, competition

Notes

1- See for instance: **http://ksgwww.harvard.edu/iip/doeconf/propp.html**

2- See for instance **http://www.ngcan.com/datacomm/powrnet/pwrnet.htm** and **http://www.hth.com/plm-24/**

3- For instance Iberdrola's automated meter reading (AMR) system in northern Spain.

4- Source: Global Technology Business, 2/98.

5- Network adaptation cost for the operator could range between 450 and 675 ECU per line, where feasible, and terminal equipment costs are on average around 3,400 ECU per user on pilot sites (Source: Analysis).

6- In Europe, out of the 40 millions CATV subscribers, there are currently only 4 million cable subscribers to either telephony or internet-type service (Source ECCA).

7- Which can be seen as extraterrestrial WLL.

8- The rocket carrying 12 Globalstar LEO satellites that crashed on takeoff in September 1998, is a setback to the high-tech industry's race to construct satellite-based communications networks.

9- It should be stressed however that a 1994 resolution (94/C 379/04) called for non-discriminatory access for all providers and users to the space segment, and that satellite consortia are under a restructuring process.

10- The UK Radiocommunication Agency however reckons that DPL's interference problem could be solved within a year, particularly with the use of spread spectrum technology.

11- Based on estimates. NOR.WEB has not released any price to date, but confirms it will be positioned competitively vs. DSL.

12- Except countries with high cable penetration.

13- It would be a false debate to position PLC against cable. It should rather be viewed as one avenue for power utilities to enhance their portfolio of services and to increase customer retention at the eve of the liberalization of their sector. Just as much as UK cable operators started to offer telephony when the regulatory framework allowed them to do so.

14- The flat local calls invoicing in the USA is indeed among the factors explaining why the number of internet users in the US is so much higher than in Europe.

15- Status of voice communications on Internet under Community law and, in particular, pursuant to Directive 90/388/EEC OJ C 006, 10/01/1998.

16- Speech by Herbert Ungerer - IIC TELECOMMUNICATIONS FORUM - Brussels, CCAB, 6 & 7 July 1998.

17-Telecommunications Act of 1996. See also NTIA's filing **http://www.ntia.doc.gov/ntiahome/fccfilings/sec706.htm**

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Europe and the Challenge of the Brain Drain

Sami Mahroum, *IPTS*

Issue: Increased demand for highly-skilled personnel worldwide and a broadening range of international education opportunities will inevitably exert pressure on the European stock of highly-skilled labour. Europe needs to be aware of these changes and other developments in international skills supply and demand.

Relevance: Europe could be losing its brightest and best scientists, academics, managers and engineers. In particular it could be losing the younger S&T and managerial personnel, who are probably those with the most up-to-date training.

Introduction

The labour market for skilled professional personnel is becoming increasingly globalized in terms of both supply and the demand. Overseas students, for instance, account for an ever greater proportion of the university population in most industrialized countries, and international mobility schemes for researchers are available at most universities. Multinational companies too draw more than ever on personnel with high qualifications from around the world to enhance and ensure a high-quality performance.

What is a Brain Drain?

'Brain drain' is defined by the encyclopaedia Britannica as the *"departure of educated or professional people from one country, economic sector, or field for another usually for better pay or living conditions"*. The OECD report (1997) on the movement of highly skilled people identifies two main basic concepts regarding Brain drain: Brain exchange and brain waste.

Brain exchange implies a two-way flow of expertise between a sending country and a receiving country. Yet, where the net flow is heavily biased in one direction, the terms "brain gain" or "brain drain" is used. A further term, 'brain waste', describes the waste of skills that occurs when highly skilled workers migrate into forms of employment not requiring the application of the skills and experience applied in the former job (OECD, 1997)[1].

Recently, Johnson and Regets (1998) have introduced a new concept into the debate, namely 'brain circulation'. This refers to the cycle

The labour market for skilled professional personnel is becoming increasingly international

'Brain drain' implies a net loss of expertise resulting from flows of skills being biased in one direction of moving abroad to study, then taking a job abroad, and later returning home to take advantage of a good opportunity. The authors believe this form of migration will increase in the future, especially if economic disparities between countries continue to diminish. Such circular migration has been observed amongst Malaysians who had studied in Australia, for example.

Flows of skilled personnel are influenced by a number of factors, including increasingly international training and the needs of international business

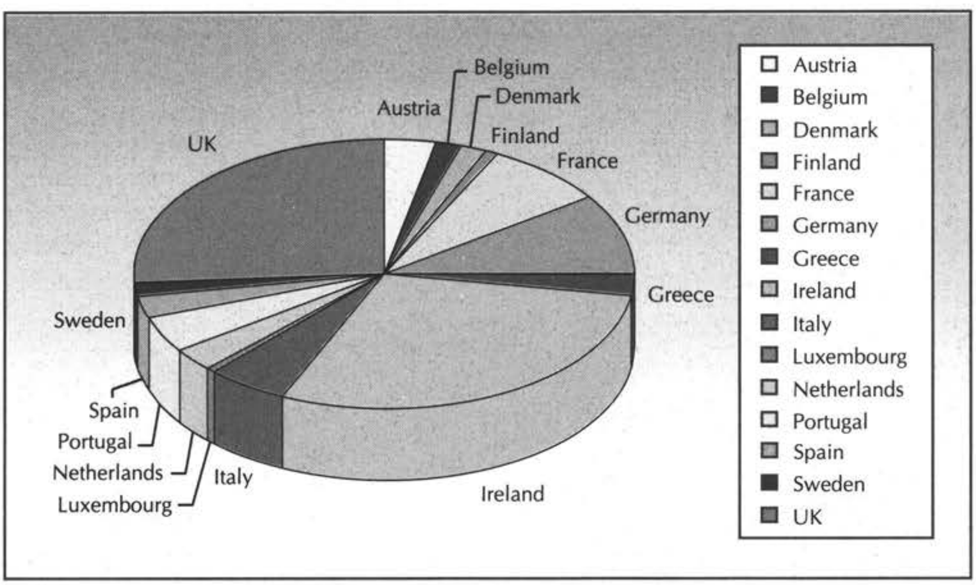
The International Mobility of Highly-Skilled Personnel

In an OECD study carried out in 1997[2], it was stated that "despite the importance of migration by the highly skilled to the development and management of international economy, knowledge of the patterns and processes of their movement is poor". A typology which accommodates the diversity of this group, and its sub-categories, is still lacking and there is no agreed concept or definition of the highly skilled.

The flows of skilled personnel are influenced and determined by a variety of factors. Firstly, on the supply side, science is becoming more internationalized than ever. Participation in international education and training, including the various international exchange schemes and fellowships, has stimulated the interest of young scientists in working abroad and has helped give domestic graduates a more international perspective (Stein et al. 1996). Smaller countries, such as Sweden, Holland, and Ireland, in particular, are seeking to produce more graduates with international experience suitable for work abroad, in order to cope with their growing international businesses activities.

Secondly, on the demand side, call for highly skilled personnel with international experience is on the rise. Local shortages of certain types of expertise are among main motives for recruitment from abroad, especially, employers seeking top quality candidates (Stein et al. 1996). Immigration incentive policies are also a factor in many countries where such policies exist.

Figure 1. Distribution of EU migrants to the US



Is there a flight from Europe?

The overall volume of European migration to the US has been more or less steady over the last few years. The number of immigrants to the US from Europe in 1994, 1995, 1996 totalled 62,658, 44,870, and 46,776 respectively. In 1994 the numbers were higher than in 1995 and 1996 due to changes in US immigration law that allowed many students to stay on.

Who is going abroad and where from?

Emigration varies across Europe. The UK and Ireland rank highest in the total number of migrants they send abroad (see Figure 1). The UK also topped European countries in the number of professionals migrating to the US (2,934), followed by Germany (1,501), and France (688). Figure 1 above provides a good picture of the distribution of EU migrants in the US in terms of citizenship. Of these immigrants, around 25% went to California, making the largest single group, around 10% went to New York state, and around 8% went to Massachusetts (US INS sources).

The Number of Professionals

7,638 EU professionals were granted permanent US visas in 1996. These included executives, architects, engineers, surveyors & mapping scientists, mathematicians & computer scientists, natural scientists, doctors, nurses, and pre- and post-secondary teachers.

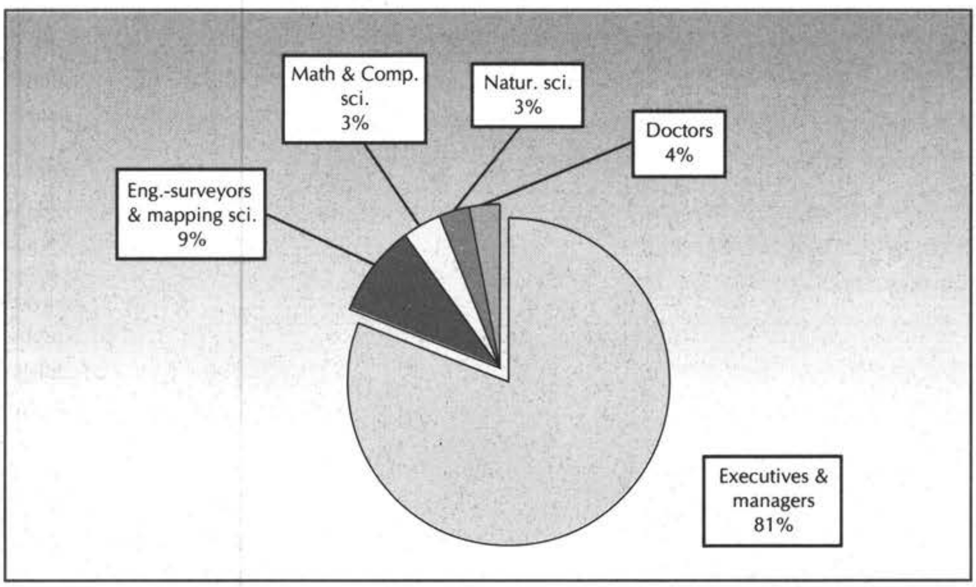
Figure 2 shows that the broadest group of professional EU immigrants to the US is made up of those who have executive and managerial occupations (4324 persons). These often originate from temporarily intra-corporate transfers that turn later into long term and permanent ones.

Academic Emigrants

About 50% of all Europeans completing a Ph.D. in the US stay on for longer periods afterwards, and many of them stay permanently (Finn, 1997). This also could be reflected in the National Science Foundation (NSF, 1995) data on European doctorate holders. The data show that in 1995 there were around 17,000 Europeans who had remained in the US after having completed

Figure 2 below shows executives and managers to be the largest professional groups of migrants from the EU to the US

Figure 2. Distribution of EU migrants by Occupation



Europeans are much more likely to stay on in the US after receiving a PhD than their Japanese or Korean counterparts

California, New York state and Massachusetts are the most popular locations for highly-skilled Europeans

The US offers 'centres of excellence' together with flexible career structures, high living standards and a strong entrepreneurial culture

their Ph.D. Of these around 11,000 had become naturalized citizens, and about 3,900 of them had become permanent residents. These include Ph.D. holders in all fields.

In science and engineering, 8,760 of Ph.D. students graduating in the period between 1988-95 (7 years) were Europeans. The US Department of Labor statistics show that over half of these are still in the US even 5 years after graduation (Johnson & Regets, 1998). European doctoral graduates have a **much higher stay rate in the US than their Korean and Japanese counterparts**. The difference between Japan and Europe in the propensity to stay is large; only 8% of Japanese Ph.D. graduates stay.

Graduates from the UK have the highest stay-rate in the US. Whereas, most German graduates go back (approx. 75%), only around 30% of UK graduates do. Greece lies somewhere in the middle between Germany and UK with a return rate of approximately 60%.

However, there are also large variations between fields of study. If we take the UK as an example, 73% of engineering graduates stay compared to 65% of those from the Life sciences, and 60% in Physical sciences. Additionally, it is perhaps interesting to note that in 1996 1000 of the Ph.D. graduates who started their own businesses in the US were Europeans.

The "Brain Drain" and the Role of Excellence

Despite the US being the main destination of European migrants they tend to be attracted by just a few places. California, New York state, and Massachusetts remain the most favourite destinations for European scientists and engineers and other highly skilled personnel (US INS sources 1993). Similarly, in a study on brain drain from France to the US (CNRS, 1997), it was found that the States of California, Massachusetts, and New York attracted most French post-docs to the US. These places seem to have certain specific dynamics that give them advantage over other centres in attracting top scientists and engineers, and thus hosting top research.

The key difference between the American and European experience resides in scientific capability. It is true that European research institutes may perform better in some fields than the US, **but they lack the magnet power that can transform them into pivotal points in their fields. European universities, for example, attract fewer international students than US universities do** despite the fact that tuition is free in many European universities (European S&T Indicators Report, 1997).

The presence of centres of excellence in certain locations and their absence in others represent two major pull and push factors. The US seems to have many such centres, combined with flexible and open career structures, a strong entrepreneurial culture, and high living standards and quality of life. For instance, when in 1996 the German Research Society sponsored 1028 German fellows to go abroad, 641 (approx. 60%) chose the US as a destination. Similarly, in Europe, Switzerland, a country that hosts major research and academic centres (such as CERN, the IBM Lab near Zurich, and the Federal Institutes of Technology in Basel, Lausanne, and Zurich) and which enjoys living standards which are among the highest in Europe, is also successful in attracting Ph.D. candidates from other European countries (26% of that country's candidates)[3].

This scientific pull, in turn, has a knock-on effect that drives all sorts of other related activities in the location in question, thus, attracting even more scientific activities. The inflows of doctoral candidates, post-doctoral researchers, and senior scientists provide the receiving countries with a pool of knowledge that places these countries in an advantageous position with regard to their competitors. Zucker, Darby, and Armstrong (1994) report that for an average firm, 5 articles co-authored by an academic star and the firms' scientists result in about 5 more products in development, 3.5 more products on the market, and 860 employees.

The IT sector, a case in point

The IT sector in the US is widely believed to be suffering from staff shortages. As a result, the US IT sector is feared to be draining other countries. However, more recently this has been challenged by some studies in the US, which have accused firms in this sector of preferring foreign engineers recruited from developing countries who are willing to accept lower wages than their native counterparts. In a Workshop organized by the Sloan Foundation in the US dealing with the issue of "Migration of Foreign Scientists and Engineers to the US" in 1997, the following remarks were made. Professor Paul Ong of UCLA (University of California in Los Angeles) found that immigrant engineers were paid up to 30% less than their native peers. Furthermore, an investigation carried out by Norman Matloff of UCLA found that only 2% of 120,000 annual employment applications to Microsoft are accepted, hardly an indicative of the claimed shortage.

In the same workshop another study carried out in the US by Robert Zacher of the Harvard Smithsonian Observatory was presented. The study found that the US is now training 2 Ph.D. scientists for every available job. The Immigration and Naturalization Services too did not think the IT industry lobby will succeed this time in increasing its quotas of foreign workers or to relax any further immigration policies. The mood in the US towards this issue seems to be changing. The demand for foreign skilled personnel is associated with the search for cheaper labour and not a response to shortages in supply.

Immigration policies of this type, however, usually target cheaper labour, drawn from countries with lower living standards than those in the EU. The push and pull factors for the international mobility of skills between advanced countries revolve around competing for excellence. Individuals search for excellent career opportunities, and organizations are looking for top quality individuals. It is where supply and demand meet that excellence is produced and maintained.

Implications

Developing and developed countries feel the impact of labour market changes on the mobility of highly-skilled labour in different ways. For developing countries it might be argued that their balance of payments has benefited more by sending people abroad from where they can send home substantial amounts of cash. In Europe, however, this is not usually the case and the negative effects of the migration of highly-skilled personnel is not outweighed by any cash they may send back, given the smaller differentials.

Brain drain fears in Europe centre on the so-called *la crème de la crème*, i.e. "star scientists" who are the brightest and best and whose talents can have many spillover benefits for their host countries. For example, in the past, European researchers in the US have always been an important source of input to the their host country, in particular many US Nobel prizes winners came from Europe. Also, the fact they are often recruited on a competitive basis tends to ensure they are of above-average quality. The majority are also young, between 20 and 40

In IT at least, immigration may be driven more by firms wanting to hire skilled personnel willing to accept lower wages rather than actual shortages

European concern focuses on the danger of losing its 'star scientists' given their pivotal role in innovation-related competitiveness

The migration of top European scientists may have a determining influence on industries such as biotechnology

years old, thus, in their most productive years. Moreover, the pull factors that attract them tend to be different from those that attract scientists from developing countries.

In the context of European emigration, "excellence" and "chain-effects" are central to the issue. The quality of the recruits from Europe might have a positive chain-effect on their employers' ability to attract more high-quality staff. This mechanism is observed for instance among mature students recruited by American universities (Lambert, 1992). Universities that recruit top performing academics tend to attract top students too (Ibid.).

The fact that significant numbers of top European scientists are abroad could pose a serious challenge for Europe in certain emerging sectors such as the biosciences. For instance, it is believed that historically research on the contraceptive pill moved from Europe to the US as a result of European scientists emigrating during the post-war era (Marks, forthcoming paper)[4]. A study by Zucker, Darby, and Brewer (1996)[5] on the rise of the biotech industry in the US, commented that *"we conclude that the growth and diffusion of intellectual human capital was the main determinant of where and when the American biotechnology industry developed [...] Intellectual human capital tended to flourish around great universities."*

Policy Implications

Once abroad Europe's scientists often find it difficult to return. The private sector could play a bigger role in absorbing European repatriates and in encouraging them back. The public sector alone cannot absorb all these talents. In the US the private sector employs the greatest proportion of Ph.D. graduates (approx. 30%) after the academic sector (NSF, 1995). The private sector can play a very useful role in joint ventures with the public sector whereby research and engineering centres of excellence could be set up across Europe. This would inevitably change the situation from an eventual "brain drain" to what some have referred to as a "brain circulation" (Johnson & Regets, 1998).

Keywords

braindrain, competitiveness, education, training, innovation, skilled labour

Notes

1- This report was drafted by Professor John Salt at the department of Geography, UCL.

2- Entitled "International Movements of the Highly Skilled" Occasional Papers N0 3.

3- Source: Second European Report on S&T Indicators 1997, Page 643.

4- To be presented at the American Historical Association Conference in January 1999.

5- Zucker, Darby and Brewer (1996).

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Photoreceptor Proteins: Smart Materials for the Electronics of the Next Millennium

Petra Düx, *VDI*, and Prof. Dr. Klaas J. Hellingwerf, *University of Amsterdam*

Issue: Proteins may be described as "smart materials". They exhibit dynamic performance at the molecular scale, a feat not yet achieved by technology. In particular, photoreceptor proteins are able to convert light directly into a signal. Developing technical applications making use of the opto-electrical mechanisms of these photoreceptor proteins could meet some of the increasing demands from state of the art information technology.

Relevance: Information technology, and with it microelectronics, will continue to be one of the major growth areas over the coming decades. Extrapolating existing trends in decreasing size, increasing storage density and falling costs runs up against challenging physical obstacles. However, some of these obstacles could be tackled by input from biological systems. Strategic funding concepts involving academia and industry, more extensive interdisciplinary training and standardization would foster these promising interdisciplinary technologies.

Introduction

Current trends towards ever-smaller computing chips will come up against increasing physical limitations. Learning from nature's example and adapting its molecular functional units, proteins, to uses in electronics may be a way forward

The current trend in information technology is towards shrinking dimensions down to the macromolecule scale (nanometer range). This will result in higher production costs and give rise to physical effects that will complicate the design of common technological systems. Thus, if IT is to continue developing in this direction, it would benefit from smart materials which are able to offer optimal performance from such small structures.

Protein molecules are the workhorses of cellular function. Operating at molecular level they play a role in catalysis, signal generation, protection and barrier functions. Evolution has optimized them so as to produce dynamic performance at the molecular scale in ways unattainable by current technologies. A major challenge for the engineers of the 21st century is to learn from nature's smart constructions and to find ways to build-in proteins as functional units in technological devices. The IPTS Report has already described the use of proteins in biosensor technologies (Demicheli, 1996), where specific interactions of molecules with proteins can be utilized for sensing, i.e. glucose for diabetic diagnoses or alcohols in drug analysis.

Photoreceptor proteins are proteins which are able to convert light directly into a signal. This process involves formation of an electrical dipole and is accompanied by a change in the colour of the protein. It is these opto-electrical features that enable them to be utilized as a "smart material". During the past 30 years biochemists have analysed the structure and functioning of such proteins in detail. Bacteriorhodopsin (BR) is the best studied example of a photoreceptor protein and has a variety of technical applications, as described below in more detail.

Bacteriorhodopsin (BR) is found in the membrane of certain bacteria, where it absorbs light to convert it into cellular energy for the bacterium. Structurally it is very similar to the mammalian visual pigment rhodopsin. Photoactive yellow protein (PYP) is also a bacterial protein, exhibiting the same photo-kinetic and photochromic characteristics as BR. Since PYP is water-soluble it is more appropriate for applications where an aqueous solvent is used as the optical medium and light scattering needs to be minimised.

A number of other photoreceptor proteins could also have technical applications. In 1985 for instance Deisenhofer, Huber and Michel received the Nobel Prize for determining the structure of the photosynthetic reaction centre. This membrane protein is the site of photosynthesis where light energy is converted into electro-chemical energy. Technically it is interesting because of the fast exciton and electron transfer that it mediates.

Technical applications of Bacteriorhodopsin (BR)

When BR absorbs light it undergoes a series of structural changes accompanied by alteration in colour of the protein. During this process a positive charge is transferred from the inner to the outer side of the cell, which is the basis for the subsequent energy storage mechanism in the bacterium. Various aspects of the light conversion process can be utilized separately for a series of different technical applications [Hampp, 1998]:

- When illuminated, BR transports charge in one direction and builds up electrostatic energy. This mechanism has potential technical applications in photovoltaic technology and their realization of photovoltaic cells based on the photosynthetic reaction centre can be expected in about 10 years [Hampp, 1998], although initial prototypes of can be expected much sooner (Nicolini, 1996).
- The charge transfer brought about by illuminating BR can also be used to generate an electrical signal. This photoelectric property can be utilized for photoelectric picture converters, such as motion sensors and artificial retinas. Development of the first prototypes can be expected in 2-3 years (Hampp, 1998).
- During the light-energy conversion process BR changes its colour in a series of steps. This photochromic property can be exploited for light-modulators, non-destructive material testing and high-resolution displays. Prototypes in this field are already being developed and are awaiting market launch (Hampp, 1998).
- Genetic engineering techniques may be used to stabilize the two natural states of the BR molecule such that it is possible to switch between them using light of different colours. By assigning the binary values 0 and 1 to the two states an ensemble of BR molecules could be used to store data. Since it is possible to stack several BR-films on top of one another, attempts are underway to develop BR-based 3D memories. The relatively small size of the protein would mean BR-based memories could offer huge storage capacities per unit volume.

The future of the 'biochip'

The 'biocomputer' or 'biochip', as we shall understand it here, refers to computer or chip-related material produced by a living organism.

Bacteriorhodopsin (BR) is a naturally occurring protein found in the cell membrane of certain bacteria where it absorbs light to generate energy

The photoelectric and photochromatic properties of BR suit it to a variety of applications such as photovoltaic cells, sensors and even high-density memories

Although the biochips may not be ready to compete with their silicon cousins for some time, the simplicity of the manufacturing process makes them ideal for high-volume disposable items

Although this approach offers the possibility of significant potential savings in cost and size, it is still some way from becoming a reality. During its national programme for bioelectronic technologies the Japanese Economic Planning Agency announced that it did not expect to see the first 'biocomputer' before 2020 (Ostasien-Institut, 1992).

A group at Syracuse University led by Prof. Birge is exploring the use of the photoreceptor protein BR in optical three-dimensional memories and parallel associative processors (Birge, 1992). However, technical viability is not yet assured; many of the key optical components required are still in the development stage and managing the undesirable physical properties of the protein requires complex technical solutions (Birge, 1997).

Other organic materials have allowed the first steps to be taken towards technical realization of polymeric computer technologies. For instance, the Canadian Bell Labs' (AT&T/Lucent Technology R&D) already claim to have produced polymer transistors (Bell Labs news, March 1998). They have been working in collaboration with a Norwegian company, Opticom ASA, which claims to be the first company to have developed a memory and processing architecture which can operate exclusively with organic components (Opticom ASA, 1998). Also, the Dutch Philips Research Laboratories have succeeded in developing complex all-polymer integrated circuits on flexible wafers (Drury et al., 1998). The simplicity of the manufacturing process compared with ordinary silicon lithography promises very cheap circuits in the future. However, the performance of the all-polymer circuits built so far is much less impressive than what is currently possible using silicon-based technologies. Nevertheless, computational speed and power are not essential for the applications that the proponents of the plastic electronics have in mind. The combination of potentially low cost and mechanical flexibility makes these materials ideal for disposable, high-volume, electronic products, such as consumer items or luggage labels (Ziemelis, 1998). Several technical solutions for increasing polymer conductivity are foreseen which could be realized in the next 5 to 10 years. Still, the question remains whether these polymer systems can perform comparably to what will be possible with silicon-based systems at that time.

International R&D activities in protein-based bioelectronics

Researchers in Europe are also currently developing bioelectronic/bioelectric devices based on photoreceptor proteins. With the financial support of the German Ministry for Education, Science, Research and Technology a research group under Prof. Hampp at the University of Marburg is developing BR-based systems in collaboration with scientists from biotechnology (Prof. D. Oesterhelt, Max-Planck-Institute for Biochemistry, Martinsried,) and machine engineering (industry). To date they have developed a number of BR-based electrical devices including holographic pattern recognition, holographic interferometers for non-destructive testing of ceramics, and high-resolution displays.

In Italy a research programme in the bioelectronics field is being conducted by the Fondazione El.B.A. (Advanced Electronic and Biotechnology). This organization grew out of the national programme for bioelectronic technologies (Polo Nazionale Bioelettronica, PNB) in collaboration with the Russian Academy of Sciences and the Jefferson Cancer Institute in Philadelphia, USA. The El.B.A. has enjoyed success in projects with microelectronics and biotechnology, but in order to improve on its results, under the leadership of Prof. Nicolini, it set up a Science and Technological Park on the island of Elba, and this is now working extensively with industry internationally on photoreceptor protein devices for displays, motion sensors, and photovoltaic cells.

Thanks to Japan's concern to maintain its dominant international position as an electronic device producer, in 1986 "Biosensor, Biodevice and Biocomputer" became a major national R&D programme under the ministry for international business and industry (MITI) (Ostasien-Institut, 1992). Although the special MITI programme finished in 1996, industry is still carrying on bioelectronics-related R&D activities. Patent application data reveals Fujitsu and Sanyo Electric Co., for example, to be active in the development of BR-based electronics.

In the US, the Defence Advanced Research Projects Agency (DARPA) has issued a number of grants for Small Business Innovation Research (SBIR) into BR-based systems. In the last 6 years these grants were awarded to eight different SME's, which are collaborating with research groups from American universities on these projects. The project topics include laser protective lenses, spatial light modulators, high-speed holographic cameras, interferometers for real-time monitoring of crystal growth, and 3D optical memories (Database of DARPA).

Marketability and measures needed

A series of technical advantages give photoreceptor protein-based electronic devices the edge over common technologies. In the case of BR, as an example of a photoreceptor protein, these include:

- The fact that BR's opto-electronic properties are reversible means write/read/delete-cycles and/or lifetimes many orders of magnitude higher than those for synthetic pigments.
- The sizes of the photoreceptor proteins are in the nanometer range. Additionally, photoreceptor proteins are regulated by light, which gives them the advantage that photon-fluxes ('light emission') can be made to converge at higher densities than electric currents. Together these two factors enable higher resolutions for use in displays, pattern recognition, light sensing and non-destructive materials testing. For data storage, the small size of BR molecules would make it possible to create BR-based memories with huge capacities.
- As BR is located in clusters in the bacterial membrane (in the form of two-dimensional protein crystals) it is easily incorporated in technically utilizable polymer films. This simplifies production and lowers the production costs of biochips based on it. Also, scaled-up BR production has already been developed, with growth of BR-producing bacteria in 10 m^3 fermentors, allowing batch production of hundreds of grams of the protein.
- Materials based on photoreceptor proteins are not only flexible, but also non-toxic and recyclable. In microelectronics, for example, bacteriorhodopsin is being tested as a functional matrix-element in a new non-toxic micro-structuring technology for silicon substances or printed circuits.

The technical development of a series of BR-based systems may already be foreseen in the short to medium term. These systems make use of light-initiated charge separation in BR (applied for instances in photovoltaic cells) or conversion of light into electrical signals by BR (applied for instance in photoelectric picture converters). However, only comparison with the performance of existing technologies once the first prototypes of such devices have been developed will prove their marketability. Moreover, the compared technologies are often based on quite different

A number of projects are underway around the world. Products under development include holographic cameras and interferometers for non-destructive testing, light modulators and 3D optical memories

Photoreceptor proteins are regulated by light, which can be made to converge at higher densities than electric currents, thus permitting greater miniaturization

As well as being flexible and non-toxic, the protein can be produced cheaply in fermentors in large quantities physical principles, so standards have to be set as to which parameters can be used to compare their performance effectively.

Prototypes of BR-based electronic devices which make use of BR's photochromic property (i.e. the fact that it changes colour under illumination) have already been developed and will now have to face the test of the market. An example of a successful technical realization of a BR-based system is a high resolution display giving a resolution of 100 lines per mm, as compared with the 4 lines per mm offered by commonly available displays. These BR-displays are highly suitable for tele-medicine, where high-resolution images and well-defined contrast is important for diagnosis (Hampp, 1998).

Introducing products incorporating photo-electric proteins onto the market is made easier if developed in conjunction with target sector industries

Clearly, however, the successful market introduction of a promising new technology depends not only on its ingenuity, but also on the right marketing process. Technologies have frequently failed commercially because their marketing failed to convince target markets that adjustment to the new technology would be profitable. A key to getting round this is to develop new technologies collaboratively involving both system developers and target industries. The Marburg team's success story with the development of a BR-based holographic interferometer for non-destructive testing of ceramics in collaboration with a ceramics manufacturer illustrates the point. Government funding for the project was split between a team of biotechnologists, mechanical engineers and computer scientists who worked on the prototype development, and a ceramics manufacturer who carried the industrial testing and adjustment of the new interferometer-system. In this way, the development of a market relevant technology appropriate for its target industry was ensured, broadening the acceptance of the new technology by target markets.

In order to give these new technological developments an even stronger push, education in bioelectronics is already being organized in Japan. The Science Council of Japan is promoting measures to ensure that bioelectronics is one of the subjects on advanced university courses. In addition, the Tokyo Institute of Technology has been offering Bioelectronics as a new course at the faculty of biotechnology since 1988. This approach guarantees more extensive dissemination of knowledge about biomaterials among the engineering community (Ostasien-Institut, 1992). However, questions can be raised as to whether specific educational programmes in bioelectronics are necessary, or whether close interdisciplinary co-operation in the respective research programmes might be sufficient for knowledge transfer.

As a final note it should be mentioned that in this new interdisciplinary field, which lies at the interface between electronics, computing and biology, nomenclature is still a serious obstacle to efficient communication. Definitions of terms such as bioinformatics, biocomputing and biochip vary greatly. To avoid misunderstandings and develop a distinctive scientific language, it would be of great benefit if an official organization could establish clear definitions for the broad range of new interdisciplinary items. As an example we have proposed here the definition of a biochip as a chip in which incorporates material produced by a living cell and that functions in a way deriving from its biological function.

Keywords

Bioelectronics, photoreceptor proteins, international competition, standardization

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The Triple Helix Model: a Tool for the Study of European Regional Socio-Economic Systems

Riccardo Viale and Beatrice Ghiglione, *Fondazione Rosselli*

Issue: The Triple Helix model, introduced during studies of innovation economy, could be considered a useful analytic tool for the study of European regional socio-economic systems.

Relevance: The Triple Helix model could help useful conclusions for regional S/T policies to be drawn.

In recent years we have seen an intertwining of business, research and government in what may be described as a "triple helix" of actors, institutions and regulations

The actors in the process are drawn from academia, government and business. Although each of these has its own culture, they are converging

A Definition of the Triple Helix

In recent decades we have witnessed a convergence and crossing-over of three worlds which were once very much separate: public research, business and government. This convergence has been represented and explained by Etzkowitz through the Triple Helix model (CESPRI, 1997 and Etzkowitz, undated), which was further developed by Leydesdorff who has provided theoretical systems with which to develop the idea (Jones-Evans, 1997, Leydesdorff, 1996 and 1997). This model refers to a spiral (versus traditional linear) model of innovation that captures multiple reciprocal relationships among institutional settings (public, private and academic) at different stages in the capitalization of knowledge. These three institutional spheres which formerly operated at arms' length in liberal capitalist societies are increasingly working together, with a spiral pattern of linkages emerging at various stages of the innovation process, to form the so-called "Triple Helix."

The model of the Triple Helix resulting by the final convergence of these three worlds could be represented by three factors: the actors, the institutions and the rules and regulations.

Actors

This is the "micro" level where the evolutionary characteristics of the model are most clearly visible. The actors perform according to roles and models of action which involve various and varied cultures which were once separated and belonging to the three worlds: academia, government and business. These three worlds are therefore converging:

- Academic researchers become entrepreneurs for their own technologies.
- Entrepreneurs working in a University laboratory or technology transfer office.
- Public researchers spend time working in a company.
- Academic and industrial researchers manage regional agencies responsible for technology transfer.

Institutions

The "meso" level relates to institutions: it is these that organize production and make use of the technological knowledge. We can divide them into three sub-categories: 1) the "hybrid agents of innovation", such as university hi-tech spin-offs, or venture capital societies set up by universities.

They are directly responsible for the production and use of knowledge and are hybrid forms of interaction between university, business and government, 2) the "innovation interfaces" between business and research; 3) and "innovation coordinators" responsible for coordination and management of the various phases of innovation activity. Among 2 and 3 are to be found all those institutions operating as a support to traditional research institutions, such as regional technology transfer agencies. Their task is to take a top-down approach to organizing the interactions between enterprise and public research, dissemination of technological know-how in the region, etc.

Regulations

This "macro" level is essential in order to set guidelines for policy incentives: the actor will make decisions according to the normative framework and to the financial incentives already on the ground.

In addition to traditional S&T policy tools such as the legislation on property rights and on autonomy of universities, some effective tools have been experimented with in the US market:

- laws supporting "venture capital activities" for hi-tech businesses.
- NASDAQ, a Stock Exchange helping, among others, high-tech businesses.

Neo-Corporatist or Evolutionary Triple Helix?

The model described above is a prescriptive answer to the problems of competition and knowledge generation. However, it is also an empirical description of what is happening in various parts of the industrialized world.

There are however two different interpretations of the Triple Helix model: the neo-corporatist interpretation is focussed on reaching a consensus on activities among the representatives of academia, industry and government and with the involvement of "innovation coordinators". The coordination committees plan the integration process and there is no belief in the possibility of an endogenous evolution. These committees set up the institutions able to increase the technological output according to a top-down model.

A European regional S&T policy example is the constitution of regional technology transfer agencies in Lombardy, Italy. According to CESPRI (Campodall'Orto), in fact, 91.1% of innovative firms in Lombardy have never had contact with these centres, whereas they have frequent, direct and cooperative contacts with universities following a bottom-up technology transfer approach. Among the technology transfer centres set up in Lombardy, CESTEC is the most typical example of a top-down neo-corporatist approach: the technology transfer agency was set up by a public-private initiative but it gradually became a technical support agency for regional initiatives and it has lost its primary role as an agent for technology transfer.

The neocorporatist model is however not satisfactory in terms of the level of integration among actors, and it rarely results in innovation-related business start-ups and has a generally low technological output.

The most effective answer lies in the legislative measures supporting a bottom-up approach involving all actors. In fact no coordination or planning committee, as proved by many experiments in this field, has enough knowledge or information which is typical of the interaction among various socio-economic actors. Therefore the neocorporatist model implying coordination committees is, usually, a weak defensive answer to the difficulties of the innovation context to find integration opportunities in order to increase technology production.

At the "meso" level institutions are involved in organizing production and making use of technological knowledge

The "macro" level of the model comprises the regulatory framework shaping decision-making at the other two levels

There are two interpretations of the model: the first of these, the neo-corporatist interpretation, focuses on consensus between academia, industry and government through the involvement of "innovation coordinators"

The evolutionary model envisages a more active role for government, particularly in defining regulations and incentives

Universities can play an important role as promoters of socio-economic development in European countries and regions

The neo-corporatist model stands opposite an evolutionary Triple Helix model where the government role is limited but more crucial. In fact it has to define the normative framework appropriate for the planning of individual incentives for reorienting academic and industrial actors towards a higher level of integration. According to experience from the USA and some EU countries it seems that it is possible to obtain in terms of technological innovation, from the spontaneous convergence of industrial and academic world.

The evolutionary interpretation of the Triple Helix model assumes that within specific local contexts universities, government and industry are learning to encourage economic growth through the development of what has been called "generative relationships" (Leydesdorff & Etzkowitz, 1997) i.e. loosely coupled reciprocal relations and joint undertakings that persist over time and induce changes in the way agents come to conceive their environment and how to act in it.

As far as European countries and regions are concerned, and according to the evolutionary interpretation of the Triple Helix model, it is therefore important to stress the role universities can play as promoters of socio-economic development (Fondazione Rosselli, 1995), especially in the context of peripheral regions that are not currently recognized as technologically dynamic. In these areas the productive system is based largely on traditionally run SMEs combined with a lack of R&D investment and the weakness of the institutional support system. The evolutionary triple helix model suggests that there is a potential for knowledge-based development in these regions stressing the role that universities can play as a factor for socio-economic development within a spiral trilateral interaction between academia, industry and government.

In Ireland, for example, Trinity College University in Dublin set up the Innovation Centre around ten years ago with the specific aim of hosting companies, industrial laboratories and, most of all, to help some academic teachers to become entrepreneurs. Since then, various international campus companies have been set up and are being run by academics; international corporations have been attracted to Trinity College and have set up laboratories which share university human resources and technological equipment and which attract the best university researchers; the government as well has set up public laboratories and research centres aiming to let them interact with the enterprises present there (Gebhart, 1996).

Neo-Corporatist versus Evolutionary Triple Helix: The results of the analysis of some Regional European Innovation Systems

The following analysis of concrete regional case studies shows the relevance of the Triple Helix model for the analysis and implementation of regional innovation policies. Though technologically very strong relative to other parts of Italy, Lombardy (Campodall'Orto, 1997; Etzkowitz, 1997; Lane, 1991) is a long way behind other industrialized regions of the world. The presence of **regional technology transfer agencies** has not supported successful technology transfer experiences, as mentioned above and therefore companies tend to establish direct contacts with universities, above all the Politecnico di Milano. This reveals the public agencies, shortcomings in promoting technology transfer to business.

As for universities and research centres in Lombardy, they rarely play the role of setting up "hybrid agents of innovation", such as Science Parks. The only successful technology transfer example is the Photonic Research Centre at the Politecnico di Milano, funded by Pirelli, which implies spontaneous convergence of industry and academia and has met with approval and incentives from local government (Teknova, 1995). Notwithstanding this and a few other examples, the Lombardy universities are far from the University model as an economic actor in the technology market. In terms of innovation output from businesses, 92.5% of patents are produced by private research centres, of which 84% are produced by multinationals (Assolombarda, 1994).

Last but not least, **technology policy** concentrates on the national level and only three regional laws for innovation financing have been introduced. They have partially failed as a result of the lack of a serious technology foresight study.

In Catalonia, Spain, S&T policy over the last decade has been considerably more innovative than at any previous time. This period has been marked by a significant increase in public and private S&T funding, which translated into a considerable increase in S&T spending, human resources and infrastructure. S&T policy in some way reflects, however, a more typical top-down approach: it has led to the creation of a neo-corporationist-type triple helix of academia, government and industry relations. That is to say the relation has emerged as a consequence of the role of the state has aiming more to finance technology programmes which are being produced by the national or Catalan governments and public research structures, rather than set incentives for spontaneous university-industry relations and related technology transfer processes. In order to maintain the spirit of innovation it is therefore necessary to solve some problems in the process of technology transfer from university to industry.

Nevertheless an example of a successful attempt at university-industry collaboration is given by the Barcelona Science Park (Bellavista, undated) which describes an evolution towards more dynamic university models. This Science Park seems to take into account the need for universities to be well connected with the economic and social world as their main target. The location of the Science Park in the Pedralbes Area responds to the existing availability of research potential in that area which is where the University of Barcelona locates its most active research personnel and most important research infrastructures and services. The same can be observed in the Catalonia Polytechnic University and in the CSIC Institutes in Barcelona. The high standard location is used as a factor in attracting investment to the area. In fact the concentration of research potential is unique in the geography of Catalonia and it may be considered an important added value for the development of research, innovation and technology transfer processes. Trilateral relationships have developed: the University provided the site, the Catalonian Autonomous Government and the Spanish Government have supported the project economically and politically since its inception. The Catalonia Savings Bank regional development funds from EU have also supported the initiative. An evolutionary interpretation of the triple helix has taken place since the relationships among actors have shaped according to a networks innovation model (Campodall'Orto, 1997) where sharing information, knowledge and experience are given high priority. Within the Barcelona Science Park project the virtuous cycle of academia-government-industry relations has been translated into an integration system that involves universities, research institutes, governments, private companies, research personnel and infrastructures.

In this respect the Barcelona Science Park and the Photonic Centre at Politecnico di Milano are two promising examples of a new evolutionary triple-helix approach. These two regional case studies suggest that the Triple Helix model can be applicable to the analysis of regional S&T policies in Europe.

The Barcelona Science Park is an example of a successful university-industry collaboration

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