

known that the eclipse has no effect on the skin.

52.2% (24) viewed that the AP government was right in declaring a holiday on October 24. 56.5% (26) answered correctly that the next eclipse in India would occur in August 1999.

The above results should be an eye-opener for scientists and rational thinkers. Doctors are considered as intellec-

tuals, professionals and are often regarded by patients as their teachers and guides. Their beliefs and principles have a strong impact on the patients under their care; further any lay person would be expected to go to a doctor for clarifications of doubts and for proper instructions for viewing an eclipse. Thus, society cannot afford 'learned men' propagating wrong notions. It is

high time that rational scientific people, bodies and journals like *Current Science* and *Resonance* spread the right message across.

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## NEWS

# A triple helix of academic–industry–government relations: Development models beyond 'capitalism versus socialism'

Despite different development histories, a broad spectrum of societies, formerly conceptualized under the divergent rubrics of the first, second, and third worlds, have formulated innovation strategies based upon the deliberate elaboration of academic–industry relations through reflexive S&T policies. Newly industrializing, de-industrializing and re-industrializing nations, somewhat to their surprise, find that they share a mutual interest in fostering knowledge-based economic and social developments requiring the creation of boundary spanning mechanisms.

How should one model the knowledge infrastructure of such a global system? We proposed to study this complex system as a triple helix of university–industry–government relations<sup>1</sup>. A workshop in Amsterdam (3–6 January 1996) discussed the triple helix in various national and regional contexts. Ninety participants came from several world regions including Latin America, eastern Europe, western Europe, north America, Australia, and southeast Asia.

### Traditional bi-lateral dynamics

The Dutch Academy of Science and Engineering adjacent to an Amsterdam canal, formerly the home of the State Museum and Rembrandt's famous 'Nightwatch' painting, was the site of the opening session of the triple helix meeting. More than 200 Dutch R&D experts and foreign visitors heard Kees

Builthuis, the director of Philips R&D, discuss the relationship of the university to an R&D intensive multinational corporation. Not surprisingly, Philips looks for personnel, discipline-based research and possibly interdisciplinary research from academia but primarily relies on its own tightly-managed interdisciplinary teams for innovation inputs into its mass-consumption electronics products. Nevertheless, even though its interests are practical, Philips maintains a focused basic research effort on silicon, a topic highly relevant to its technologies.

Frigas Gelegyi, director of the Zoltan Bey Foundation in Hungary, discussed the Hungarian transition. The Zoltan Bey is the successor organization to the branch industrial research institutes under the former socialist system; now the remaining institutes are jointly sponsored by government and industry following the German Fraunhofer model. Formerly, Gelegyi was pessimistic about a role for domestic R&D, given the influx of foreign companies bringing their own technology. Although these initial fears were partially realized; having entered the Hungarian scene, foreign companies soon acquired Hungarian suppliers and these local companies, having to update their technologies to meet higher standards, needed the support of the Hungarian innovation system. Now that the technical requirements for products have been raised; real rather than formal connections to R&D sources are needed, thus Gelegyi's qualified optimism.

### The triple helix model

These two instances of academic–industry and government–industry ties exemplify older familiar bi-lateral formats of technology and knowledge transfer. The thesis of a trilateral or 'triple helix' model of innovation is that three institutional sectors (public, private and academic) that formerly operated at arms length are increasingly working together, with a spiral pattern of linkages emerging at various stages of the innovation process. Start up firms are a common outgrowth of the three sectors: arising from academic research groups, national laboratories, and the laboratories of large corporations.

There are four dimensions to the development of the triple helix model: the first is internal transformation in each of the helices, such as the development of lateral ties among companies through strategic alliances or an assumption of an economic development mission by universities. The second is the influence of one helix upon another, for example, the role of the US federal government in instituting an indirect industrial policy in the Bayh–Dole Act of 1980. When the rules of the game for the disposition of intellectual property produced from government-sponsored research were changed, technology transfer activities spread to a much broader range of universities, resulting in the emergence of an academic technology transfer profession and information media to service it.

The third dimension is the creation of a new overlay of tri-lateral networks and

organizations from the interaction among the three helices, formed for the purpose of coming up with new ideas and formats for high-tech development. At the regional level examples include Joint Venture Silicon Valley, established during the recent economic downturn, the Knowledge Circle of Amsterdam, organized during the past decade, and the New England Council, founded in the 1920s, all including participants from small and large companies, local government and academia. The discussions that took place in the New England Council meetings during the 1930s, led by MIT President Karl Compton, resulted in the formulation of a strategy for knowledge-based economic development from the regions' academic institutions that was realized after the Second World War, in part, through the invention of the public venture capital firm. Thus far, a regional computer network 'Smart Valley' and a Dutch internet industry have emerged from the new configurations.

At the national level, the topics that the US technology programs, such as the Advanced Technology Program (ATP) and Small Business Innovation Research (SBIR) address, are not rigidly set from above. Certainly they draw for general themes upon critical technologies lists or the interests of program managers. However, the agencies also call meetings on technology themes in different parts of the country in which people from small and large companies, universities and government laboratories participate. In workshop discussions on a particular area of technology, such as digital video, problems in the technology are discussed. The question posed is: what are the blockages that can be addressed through a grant program. Out of these discussions, if a consensus arises; then that becomes the topic on which a request for proposals is made. Through this format, instead of a top down planning hierarchy, a bottom up planning process is being created in the US.

### **Innovation environments**

The fourth dimension of the helix model is a recursive effect of these neo-corporatist entities (typically representing academia, industry and government in contrast to traditional European corporatist models representing government, industry and labour), both on the

spirals from which they emerged and the larger society. One such effect is on science itself as a result of internal changes within academia, strengthened and diffused by government policy.

Linkages among sectors, drawing together organizations working at different stages of the innovation process, is the next step to bringing about a new innovation environment comprising universities, national laboratories, laboratories of large corporations and start up firms. These organizations act, not separately as in the old linear model, but through various alliances and consortia, creating ties across the triad of helices (representing the academic, industrial and government sectors) whose interconnections we have only begun to model and map. These links are not only among firms in an industry but also between firms and universities, between state governments and universities and firms, and now between elements of the federal government, state governments, firms and universities.

National innovation systems are regionalized and internationalized as innovation processes take place across national boundaries, through cooperative arrangements among regions and firms. Bilateral government-industry and university-industry ties have expanded into trilateral relationships at the regional, national and multi-national levels. Encouraged by government, universities have become a key element in innovation policies throughout the world, both as a source of technology for start-up firms and older companies.

### **Normative change in science: The role of the universities**

Universities are undergoing a 'second academic revolution' as the economic function of the university is increasingly institutionalized as an overlay on the 'first revolution' that combined research with higher education<sup>2</sup>. As Judith Sutz (University of Montevideo, Uruguay) expressed it forcefully in her contribution to the conference: 'The increasing demand for funds from universities and research institutes gets a similar response worldwide: support yourselves! That is to say, connect yourselves with industries and the government, offer your knowledge and your capacity to generate new knowledge and charge for that. Only in this way, will you be able

to extend your laboratories, hire young people and increase your salaries.'

In some countries universities have suffered budget cuts of sometimes more than 20%. This does not necessarily indicate decline in terms of the knowledge production and control structures. The science system itself takes part in the transition.

The classic sociological model of the conduct of science was formulated by Robert K. Merton, based upon his analysis of such underlying conditions as the rise of protestantism, creating an intellectual climate conducive to experimentation in 17th century England. Methodological and social norms of science were implicitly formulated that encouraged the development of scientific institutions and the role of the scientist. One of these norms, defined by Merton in 1942, was 'disinterestedness,' the expectation that scientific knowledge would be freely distributed, with researchers taking their rewards in recognition from their peers.

The capitalization of knowledge has replaced disinterestedness as a norm of science. This new norm has arisen not only from the practices of industrial science and the emergence of an entrepreneurial dynamic within academia but from the external influences on the university, from government policies such as the indirect ones that changed the rules for disposition of intellectual property arising from federally funded research and from direct industrial policies, as well. Concretized in organizational forms such as technology transfer offices and the requirements of government granting programs for the support of research, the capitalization of knowledge changes the way that scientists view the results of their research.

### **Cross-national comparisons**

During the last decade, growth has been concentrated in sciences at the interfaces like biotechnology, artificial intelligence, advanced materials, etc<sup>3</sup>. Cooperative research centres are in many countries the fastest growing institutions of university research<sup>4</sup>. Tim Turpin and his colleagues from Wollongong (Australia) concluded from a comparison of developments in China and Australia that ten to fifteen years of transformation have thoroughly 'disorganized' the previously existing institutional boundaries.

Sandra Negraes Brisolla (University of Campinas, Brazil) addressed the question why Brazil had fallen behind Korea by 1985 in 'technological capacity.' In the early 1980s, at the time of the transition from military dictatorship to democracy, the roles were still reversed. The analysis concluded that Korea's successful management of the financial sector seems to have been a crucial factor. While Brazil had maintained an open market during the 'debt crisis', the Korean government managed to shelter its banking system protectively, and thereby created financial conditions for the development of a knowledge-based economy.

Brisolla proposed to distinguish (for example, national) systems in terms of their 'technological capacity' to transform the economy. Such a capacity should include relevant factors like banking, the gearing of the educational system, and the flexibilities for transformations within the relevant markets. From an evolutionary economics perspective, one is able to analyse the specificities of such a system in terms of niche creation and niche management within a global economy. Jian Tong (Chinese Academy of Sciences) contributed by specifying the categories for variation, selection, and retention in this analysis: 'In Nelson and Winter's theory, the game is played within markets and industrial firms are the only players whereas to address the triple helix analytically, academic institutions, industrial firms and government agents apparently all should be players in a game played beyond as well as within markets.'

Tong proposed to consider 'human capital' as the main variation generating factor in knowledge-based economies, 'niche selection' provides the feedback, and adaptation processes enable the institutional reproduction.

While the new regime is globally constructed, variations abound. Several papers (e.g., by Philippe Laredo and Philippe Mustar from the Ecole des Mines, Paris) focused on the deliberate attempts of the European Commission to develop transnational networks of scientists and industrialists in order to shape the European Union. Which have been the effects in terms of research and the formation of SMEs? Europe's supranational networks came on top of national programs that tended to focus more on strategic priorities (like biotechnology) than on university-industry relations. In the US, on the

other hand, university-industry relations have been a priority for lower-level (i.e. state) governments with a focus on regional development<sup>5</sup>. Thus, different dynamics can be discerned on both sides of the Atlantic Ocean<sup>6</sup>.

In comparing European countries, one finds different patterns of university-industry relations; different sectors; different technologies (e.g. refs 1, 7). But the system that came in place has characteristics that go beyond local specificity. Petra Ahrweiler (Bielefeld) in her contribution to the conference communicated how the artificial intelligence community in the German Federal Republic has consciously been developed as a 'scientific-politico-economic' community that internally discusses and decides upon the various options for developing the field. Terry Shinn (GEMAS, Paris) showed that communities that discussed 'research technologies' and scientific instruments across disciplinary and institutional boundaries have existed since the late 19th century. Problem-solving requires the use of theories as heuristics, and an orientation towards interaction with other domains. The transformations affect the nature of scientific theorizing by developing other dimensions of relevance.

The patent system, for example, has evolved to define mathematical algorithms and new forms of life as inventions in addition to more conventional innovative artifacts. Andrew Webster (Anglia University, UK) reported on a survey among British academics about the shortcomings of the patenting system to cover the new arrangements. Bill Kaghan (University of Washington, US) noted that the patent system is based on 'a laboratory model of science', while many sciences are increasingly providing innovations using a 'desktop' model. Some elements can be patented, others need copyright protection. The institutional models used by policymakers and transfer agents may require revision.

### Development model beyond 'capitalism versus socialism'

A hidden assumption of evolutionary economics has been a theory of the firm. This focus is sometimes extended to the group of companies in an industry or a heterogeneous network of companies in an industrial district. We suggest extending the analysis, especially at the

regional level, to incorporate governmental and academic actors, who play an increasing role in creating the conditions for a successful regional innovation environment.

In our view, the knowledge-based economic regime has made the distinction between *laissez faire* and active state intervention obsolete: governance means nowadays codifying high quality selections that set free new areas of activities as zones of recombinations. Magnus Gulbrandsen (Oslo, Norway), for example, showed how new developments at the interfaces of Scandinavian universities can be assessed taking as a baseline successful instances of knowledge-based economic developments like in the regions of Grenoble and Cambridge.

One expects the new opportunities (and the new jobs!) to emerge not in the existing institutions, but in careful recombinations that are based on knowledgeable reconstructions by their nature. An economic and science policy analysis which does not take account of these potentials for recombination of elements among the helices, misses the lessons from several decades of experiences in knowledge-based economic developments.

The triple helix meeting was supported by various Dutch groups including the Ministry of Education, Culture and Sciences, the Society of Technical Sciences and Engineering, the Royal Academy of Sciences, the Graduate School for Science, Technology and Modern Culture as well as the European Union and the US National Science Foundation. The organizing units were the Science Policy Institute of the State University of New York at Purchase and the Department of Science and Technology Dynamics of the University of Amsterdam.

An edited selection of papers from the conference will be published by Cassell/Leicester University Press/Pinter in a volume, provisionally entitled *Universities in the Global Knowledge Economy*, Henry Etzkowitz and Loet Leydesdorff (eds.).

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## RESEARCH NEWS

## ‘FIP-effect’ in the solar and stellar coronae

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There is currently a great controversy raging over the element abundance variation in both solar and stellar coronae. Reviews<sup>1,2</sup> of direct extreme ultraviolet (EUV) and X-ray studies of the solar corona indicate that the abundances of elements with low First Ionization Potential (FIP) < 10 eV (e.g., Fe, Mg, Si, Ca) are enhanced in the solar corona relative to their abundances in the photosphere by factors of 3 to 10. The abundances of species with high FIP > 10 eV (e.g., O, Ne, Ar) generally appear to be the same in the solar photosphere and corona. This phenomenon is known as the ‘FIP-effect’, but there is not yet any widely accepted model to explain it. The FIP-dependent variation has also been shown from solar wind and spectroscopic studies. Abundance anomalies, such as the ‘FIP-effect’, can have important consequences for the radiative loss functions and might provide new and potentially powerful diagnostics for the physical processes in the outer atmospheres of the Sun and other stars.

With the launch of ROSAT Wide Field Camera (WFC) and subsequently the Extreme Ultraviolet Explorer (EUVE), astronomers have had their first consistent access to the EUV waveband (100–1000 Å) to observe sources outside the solar system. Data from the ROSAT EUV sky surveys have allowed study of the global properties of white-dwarfs, coronally active stars and cataclysmic binaries. The possible pres-

ence of the so-called ‘FIP-effect’ from the EUVE data is indicated in some stellar coronae (e.g.,  $\alpha$  Cen,  $\epsilon$  Eri) but not in others (Procyon, for instance)<sup>3</sup>. Most numerous group of EUV sources, the active cool stars and the study of their coronae have been carried out with EUVE satellite. With a resolution of about 1 Å, EUVE has offered a unique opportunity to study individual spectral lines in stellar EUV spectra. This has allowed major advances in the field, such as the derivation of detailed emission measure distributions for the temperature range of  $\log T \sim 5-7.5$  K; and the inference of plasma densities from density-sensitive line ratios. EUVE observations coupled with IUE (International Ultraviolet Explorer) or HST (Hubble Space Telescope), have made it possible to study the temperature structure of the outer atmospheres of stars, from the chromosphere and the transition region up through to the corona. This is necessary to calculate the atmospheric energy balance, to identify and test possible heating mechanisms.

Abundance anomaly in the Sun and Procyon, whose coronae look superficially similar, has recently been investigated<sup>4</sup>. Using the same lines and the same atomic data, it could not be explained why the Sun exhibits a ‘FIP-effect’ but Procyon does not. It may be argued that the reality of the ‘FIP-effect’, even in the Sun, may be an artifact of the spectral lines chosen for the

abundance analyses. However, if the same lines and the same atomic data are used, it would be difficult to imagine a situation wherein errors in the atomic data also depended on FIP, such that when analysing solar EUV and X-ray spectra it would always give rise to the ‘FIP-effect’. Other controversies regarding earlier solar results, such as whether the assumptions of ionization equilibrium might not be applicable in some circumstances and gives rise to spurious abundance anomalies, call for detailed interesting investigation.

Consequently it appears that, while study of coronal EUVE data is very important, there is a ground for debate why the Sun exhibits ‘FIP-effect’. Thus, the study of coronal abundances promises to be an interesting field of research with space programs with high-resolution EUV capabilities, such as the SOHO satellite-borne CDS and SUMER instruments. Based on our own research<sup>5</sup>, making use of high-FIP coronal spectral lines (Ne VI: 999.6 and 1006.1 Å) to low-FIP ones (Mg VI: 1190.07 and 1191.62 Å), an important observing sequence has been planned by the SUMER team<sup>6</sup> for further studies on this topic. Meanwhile, the absence of the ‘FIP-effect’ in the corona of Procyon provides evidence that the ‘FIP-effect’ is not a ubiquitous signature of late-type stellar coronae. The available solar observations, however, provide a compelling body of evidence<sup>2</sup> that the ‘FIP-effect’ is operative in the solar atmosphere.