POLICY FORUM: RESEARCH AND DEVELOPMENT

A New "Industrial Ecology"

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At a time of rapid technological change, industry faces a conundrum. The pressures of competition demand that they use their R&D resources to keep up a steady flow of new or improved products and more efficient processes. But how can "long-term research" be integrated to ensure that breakthrough technologies are not neglected? This issue is not new: It was the core concern of the great post–World War II corporate laboratories, such as Bell Labs. However, the belief that one mammoth lab can set and cover a corporation's entire technological agenda has long been superseded by a more decentralized model. For many firms, the model of technological self-sufficiency has been replaced by a model of network relationships.

Large multiproduct, multitechnology firms such as Philips and 3M still predominate but are complemented by a dynamic population of smaller companies sustained by venture capital. Complex patterns of birth, growth, acquisition, or death of the firms in this population enable effective selection among the technologies they pioneer. This results in a menu of small technology-rich companies that larger companies can buy and take to higher stages of commercialization.

At the same time, larger firms increasingly outsource R&D to specialist private-sector research houses (*1*). The share of business-sector R&D funding spent in universities has also increased from 1.4% to 1.7% in the Organization for Economic Cooperation and Development (OECD) during the 1990s (*2*), with business funding accounting for ~6% of university research finance (*3*). Business spending on in-company R&D grew one-third faster than combined public and business funding for university research from 1993 to 1998. These diverging trends may create an imbalance: Insufficient basic research to sustain future applied research.

Globalization is also a factor in the changing industrial ecology of R&D. Foreign multinationals finance a third of business R&D in the UK, 12% in the USA. The pattern of globalization is similar across the OECD, except in Japan, where the proportion of foreign-financed R&D is much smaller. Some small, high-income countries, such as Sweden and increasingly Ireland, have invested heavily in government-funded basic research and have become attractive R&D locations for multinationals because of the combination of high-quality science and a skilled workforce. Other countries such as India have attracted R&D because of reduced cost or lower regulatory hurdles.

Also important is industrial networking: a rapid growth in collaborative R&D, alliances, and technology-based joint ventures. An estimated 20 to 25% of business revenues stem from alliances between two or more companies (*4*). These may combine capabilities across sectors; for example, a recent alliance brings together Dow Corning's silicon chemistry with Genencor's expertise in industrial enzymes to develop products using silicon biotechnology. Other alliances coordinate technology development up and down the supply chain; for example, Reuters innovates in information services through upstream collaborations with technology developers such as Sun and Microsoft, as well as downstream alliances with customers in financial services, who provide early feedback on product design.

The last decade has seen technology development move ever more firmly into the control of the business units that market products and services. Great efforts have gone into breaking down communication barriers between technology and marketing staff and into streamlining project management. But what about research?

In a recent study of six leading-edge large firms (*5*), we found strong evidence that corporate labs are moving away from the traditional, discipline-based organization. Rather, research targets are established centrally first, and groups with different expertise are formed around them. These multidisciplinary and cross-business function programs are aimed at technology leaps in strategic areas.

An example is IBM's Blue Gene project. A multidisciplinary team is engaged in a long-term effort to build a massively parallel computer that will greatly increase the speed at which protein folding is simulated. The short-term benefit to the company is the application of improved algorithms to existing work. But the real aim is a new range of supercomputers for drug discovery and nanotechnology (*6*).

These big, targeted technology programs still contain scope for curiosity-driven science at the project level, although this is not the primary focus. Reward schemes for staff promote scientific excellence and active participation in wider science networks. In the companies we researched (*5*), staff rewards and bonuses are directly related to conventional indicators of peer recognition in public science. Best practice has moved from a customer-contractor model toward "joint production of knowledge" (*7*).

Accompanying the changes in the organization and targeting within corporate research labs, we also see changes in their relationships to universities. Moving away from large portfolios of relationships with individual academics, they instead establish long-term relationships with top university departments, which cover equipment provision, staff posts, reciprocal staff appointments, graduate student recruitment, and specific pieces of contract research. In the UK, for example, Rolls-Royce Aero Engines had 300 small, dispersed university projects but now has 19 very large "University Technical Centres." Such "embedded laboratory" arrangements have been criticized for creating conflicts of interest, but are generally viewed favorably by university managers and by the academics involved. Buoyant industrial research spending and tighter links with universities should not, however, be used as an excuse for letting public funding stagnate. Public funding of curiosity-oriented research must keep pace with business funding to provide the basis for future technology breakthroughs. This is particularly important in today's "just-in-time" approach to technology generation, when even fundamental research is expected to impact on the market in as little as 2 years.

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