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REVIEW ARTICLE

# An international political economic view of the biotechnology industry

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**This paper uses a model developed from the international political economy (IPE) school, to address the structure of the biotechnology industry. In particular, by focusing upon four primary structural elements of the industry, knowledge, production, finance and security with key secondary considerations of biosafety, public opinion and choice of intellectual property regime, the development of biotechnology companies from developed countries fits within a triad dominated industry with specific interests towards firms from developing countries. The activities of a sample of US National Association of securities Dealers Stock Market (NASDAQ) quoted biotechnology firms are investigated to support the model which concludes by the observation of the need to include both strategic and traditionally non strategic interests when reviewing policy formulation and objectives for firms in the biotechnology industry.**

A cursory reading of the public press on the biotechnology industry, presents a dichotomous image. On the one hand, there are claims of unprecedented potential for growth, technological competitiveness and economic wealth to be gained from an active pursuit and investment in these areas (FCCSET, 1992; DR Report, 1996; Kyriakou and Gilson, 1998; DTI, 1999), whilst turning the page we are reminded of continuing major structural problems and ongoing difficulties in the sector (DR Report, 1997; Berliner, 1999; LaFee, 1999; Newsedge, 1999a) combined with public perceptional and biosafety concerns (Assouline, 1996; Commandeur, 1996; EFB, 1997; EFB, 1998).

In this paper, the development of the biotechnology sector from both a public and private perspective is examined using concepts from international political economy (IPE) and supported by secondary data and a sample of US NASDAQ quoted biotechnology firms. The empirical data is based upon a contents analysis of the Annual Reports of a random sample of NASDAQ quoted US biotechnology firms. Whilst the strategic information gathered from these reports does not constitute a total description of the activities of the firm, as public documents, they will stress the factors that are of primary concern to that firm and to any potential investor. The 48 firms sampled, cover a wide range of biotechnologies, sizes, markets and objectives.

There is a continuing need to increase food production, particularly in the developing countries of Asia, Africa and Latin America. And this increase has to come from increased yields from major crops grown on existing cultivable lands. One practical means of achieving greater yields is to minimise the pest associated losses, which are estimated at 14% of the total agricultural production: 52% in wheat, 83% in rice, 59% in maize, 74% in potato, 58% in soybean and 84% in cotton (Oerke et al. 1994). Insects not only cause direct loss to the agricultural produce, but also indirectly due to their role as vectors of various plant pathogens. In addition to direct losses caused by insects, there are additional costs in the form of pesticides applied for pest control, currently valued at US $10 billion annually. In crops such as pearl millet, sorghum, pigeonpea, chickpea and groundnut grown under subsistence farming conditions in the semi-arid tropics, the losses due to various

## An attractive industry ?

A review of the US Biotechnology company performance, that the sector is prone to spectacular failures and crashes as investors began to question the logic of assured high returns. In 1994 for example, US company Synergen lost $715m of its market value in a single day when its *Antril* drug failed in clinical trials (Welles, 1999). Indicative of recent UK difficulties in this sector, shares of the small biotech diagnostics firm Shield Diagnostics have ranged from a low of 103 pence to a high of 919 pence (Newsedge, 1999c). More recently, increased merger activity between the large firms and a squeezing out of the medium sized

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biotechnological company is apparent[i] with deals such as Monsanto's purchase of Dekald Genetics for $2.3b which was swiftly followed by Du Pont's buy out of Pioneer Hi-Bred International Inc for $7.7b (Holland, 1999; Kupper, 1999; Morgan, 1999; Newsedge, 1999b) and of course the previously aborted merger between Glaxo and SmithKline-Beecham. Acceptance of long lead times, decreasing investor funds (and confidence), rationalization, problems of intellectual property, healthcare policies and structural economic difficulties are rapidly maturing the biotechnology industry.

Despite these apparent problems, European biotechnology firms and policy makers have reason for cautious optimism. Compared with the Information Technology (IT) sector, the dispersion of regional biotechnological strengths is considerably wider than was the case with that sector in the early 1980s. Europe has strong traditional biotechnological activities in fermentation, enzyme production, agriculture, food processing and pharmaceuticals which endowed the large European transnationals with a significant initial competitive advantage. A dependence on these initial resources though is, as the resource based theory of the firm stresses, of limited long term benefit (Christensen, 1996; Foss and Knudsen, 1996; Spender, 1996; Zucker and Darby, 1998). In a sector where knowledge (especially new to the world knowledge) is perceived to be the primary source of competitiveness, a static or introverted / regional market perspective means advantages are quickly lost.

## An overview of an international political economy perspective

Stopford et al. (1991) developed a diplomacy model, which views industrial sector development as a result of the relationships between the triangle of interpenetrating actors from the state, the market and the firm. Lawton (1997) extended this analysis for the EU environment, by considering the role of meta and supra levels of state involvement. Importantly, this methodology allows account to be made of historically endowed and policy constructed competitive advantages. Overall by considering the interaction between different governance levels in this market sector, the evolution and capacity of those actors to shape the development of the market can be gauged. This is known as structural power and unlike the more realist driven relational power, it is the capacity of an actor / set of actors to shape and influence the development of that market sector. This can be initially achieved intentionally or by historical happenstance and in this paper, the combinations of finance, knowledge, security and production, as key factors underpinning the development of this structural power are examined in the biotechnology sector (Strange, 1988). In particular, as both Cerny (1996) and Peterson (1994) argue with the competitive state concept, the co-ordination of national support systems for industrial sectors, through the four factors given above, determines the capacity of the nation-state to support industries and hence to a certain extent, the scope those national industries and firms have for shaping the development of that global industry. Sklair (1998) adopts a more focused firm view, where an industrial sector (especially those which are globally focused), develops through four pillars of activity, yet these four pillars are themselves derived from different actor relationships of the four structural power factors. These four pillars are:

- The extent of Foreign Direct Investment (FDI)
- Industrial practises sourced from a global arena (such as benchmarking and world best practise).
- The degree to which the firms promote a global corporate citizenship in their business practises.
- The extent to which a global vision guides business activities, opportunities and profit.

Clearly, FDI is a direct component of structural power for the actors concerned, with the ability to release or with-hold capital a key consideration in an industry with long lead time and high capital demands. Industrial practises are also derived from production knowledge (a structural power factor), an issue which Kogut and Zander (1993) argue is critical for sustaining a firm's competitive advantage. Notably, these last two activities, are internal to the firm. This cursory review of IPE concepts therefore suggests that effective biotechnology firms will derive their competitive strengths and capacity to shape industrial development through a mix of knowledge, production, finance and security factors which shape and are themselves shaped by the internal organisation and activities of the transnational. Individual firms do not possess power, but are part of the system of relationships which fixes the development of the sector to certain resources and practises of the firm which may have more experience or access. One manifestation of this external – internal structural power fixing, is arguably found in market activities including collaborative alliances, mergers and acquisitions and specific institutional arrangements that underpin the competitive state concept.

Deriving from the four primary sources of structural power in the biotechnology sector, are secondary influences (Strange, 1988). These secondary influences are particularly important for some regional markets (such as the UK or Germany), although less so for others (such as the US or Italy). Three key secondary issues are the public perception of biotechnology, the most relevant intellectual property regime to implement and emergent biosafety protocols for the handling, manipulation and distribution of biotechnology products. Actors unable to effectively address these secondary concerns, can see their capacity to effect market changes and power, curtailed.

## International political economy and the nature of technological competitiveness

The IPE frameworks presented by Stopford et al. (1991), Wyatt-Walter (1995) and Lawton (1997) encompass the nature of contemporary business-governance inter

-relationships. Stopford et al.'s (1991) original triangular diplomacy model was updated by the pentagonal model presented in Lawton's (1997) analysis of EU Semiconductors policy. This model has value in that it readily identifies the major communicational and policy-making possibilities that are implicit in the broader firm-governance interface. Given differing international business sectors however, the single sectoral focus of Lawton's (1997) framework must be broadened to acknowledge that although a useful heuristic tool sectorally, the interaction between actors can be expected to vary widely for less developed policy streams such as biotechnology, reflecting existing policy competencies and success at the regional, national and European governance levels. Cantley (1999) for example stresses the nature of policy convergence when discussing biotechnology industry, with the EU Directives on contained use of genetically modified organisms (90/219) and the field release of genetically modified organisms (90/220), the context of the Convention on Biological Diversity (1993) and the proposed Biosafety Protocol (Commandeur et al. 1996) which are linked to the discussions of the WTO over the most relevant intellectual property regime to implement in developing countries (Commandeur,1996) and the Sanitary and Phytosanitary agreement (SPS). It can also be argued that Sklair's (1998) FDI firm focus will affect the relevance of the different levels of analysis presented by the model.

It is the relationship between large international businesses, nation state actors and the European Commission (via the relevant Directorate-Generales) that are the key focus to policy development and priority setting in the EU (Wyatt-Walter, 1995 ; Lawton, 1997). To this observation however should be added the significant variation in the different technological policy streams in terms of relevant actor capacities, at least partially shaped by secondary factors. This in particular identifies the bioentrepreneur as an increasing focus of such support policies (Adam, 1997; DG XIII, 1997; Nature Biotechnology, 1998; Nature Biotechnology, 1999) and the nature of the supportive environment within which they exist. A hostile environment may result in firms leaving a region in favour of one with less regulations (EFB and EMBO, 1999), threatening expected welfare benefits, just as policy making generally is seeking to associate technological, competitive and cohesive issues.

Political integrational constraints arising from the need for multiple nation-state policy support are important policy boundary factors in the EU (Lawton, 1997). The transition of technological, competition and cohesive issues out of the traditionally limited industrial policy of the EEC to more specific formal and codified industrial policy competencies within the EU, remains limited. Rather, the EU industrial arena still operates with a more functional, incremental and co-ordinational rationale, resulting in policy convergence and the emergence of multidimensional policies (Holland, 1993; Charles, 1995; Adam, 1997)[ii] Member-state policies remain important national arenas for shaping national industrial competitiveness in a melée of different locational and resource conditions. Only very recently with the 1998 European Biotechnology Patent Directive, has pan EU protection and support been available.

This observation embraces the notion that the home base of the firm remains the core source of its competitive advantage (Ring et al. 1990; Dunning and Cantwell, 1991; Patel, 1997). It can be expected therefore that such firms would be more likely to maintain their key assets and resources in their home country rather than a host nation-state (although there may be some variations for global industries depending upon the internal geocentric orientation of the firm) (Ring et al. 1990; Dalton and Serapio, 1995[iii]; Wyatt-Walter, 1995; NSF - Science and Engineering Indicators, 1996). As such, national competitive advantage can be largely maintained within 'nationally' controlled factors (Mitchell, 1997b). Importantly, in the biotechnology sector, nationally controlled factors can be further ensured through the relationships nurtured between developed biotechnology countries and those developing competences in biotechnology. Headlining this concern is the TRIPs (Trade Related Intellectual Property) agreement and the development of (indigenous) developing country patent protection systems (Seiler, 1998).

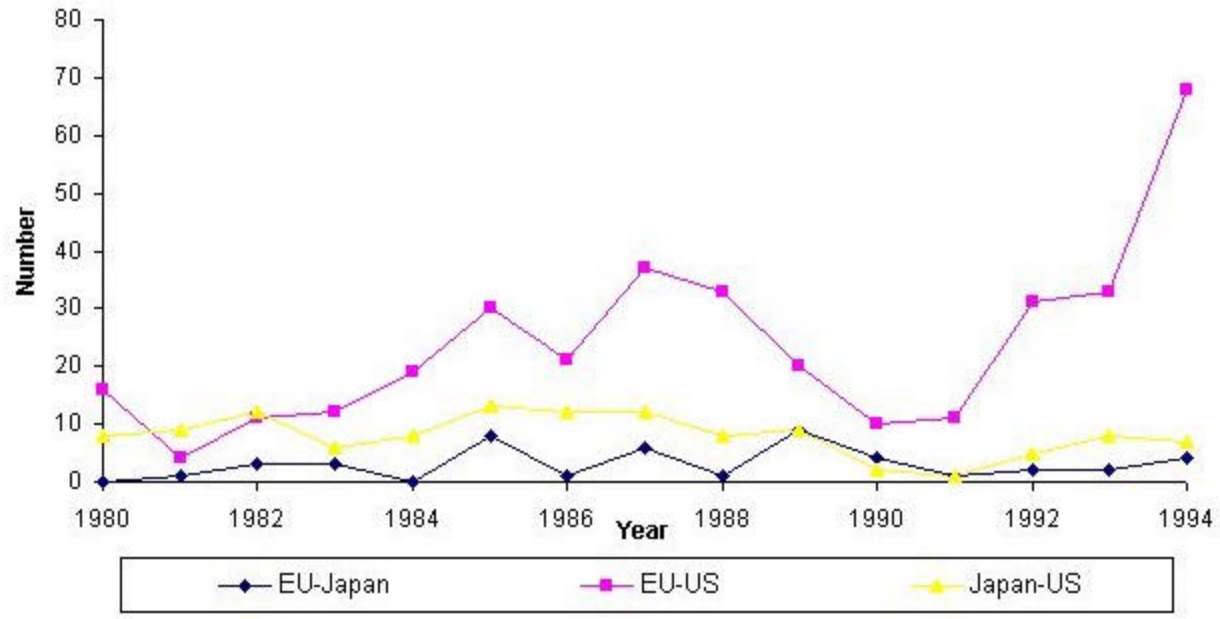
Overall, this is the familiar argument of Peterson (1994) and Cerny's (1996) competitive state. For example, US international firms in the high technology industries, continue to perform approximately ninety per cent of their basic research within the US (Dalton and Serapio, 1995). A review of the preferred collaborative partners (a key competitive tool in the biotechnology sector) of a random sample of NASDAQ quoted biotechnological companies, continues to stress the importance of US partners, especially for research and development activities (**Table 1**).

**Table 1. Origins and stated functional focus of strategic partners for a sample of NASDAQ Biotechnology Companies**

| Function | European collaborations - objectives | USA collaborations – objectives | Japan collaborations – objectives | Other regions |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Marketing | 36 | 26 | 13 | 8 |
| Production | 29 | 32 | 17 | 2 |
| Research | 42 | 61 | 7 | 0 |
| Distribution | 21 | 20 | 7 | 9 |
| Licensing | 26 | 46 | 10 | 0 |

From **Table 1**, the dominance of US with US and European strategic partnering is clear. Moreover, it is firmly focused in research and development. Collaborations with Japan based biotechnology firms favour local marketing and production determined by market access constraints, although Japanese firms generally have stepped up their overseas business activities since the collapse of Japan's bubble economy (1991) particularly in Asia (STA, 1998). This was further aided by the relaxation of foreign ownership restrictions in Asian countries for both investment and research programme participation (BioAsia Monitor, 1998; STA, 1998). These findings also reflect the views in the comprehensive report by the National Science Review (1996) where **Figure 1** highlights differences between the absolute number of biotechnology strategic alliances established (by firm home country) between 1980 and 1994. The preference for EU – US tie ups is again clear. **Figure 2** repeats this pattern when all enabling technology strategic alliances are considered. In that figure, the number of alliances of US to EU and Japanese firms whilst increasing over the period 1980-1994, is accelerating far slower than between US and US firms.




*Source: NSF, 1996, Appendix Table 4-38.*

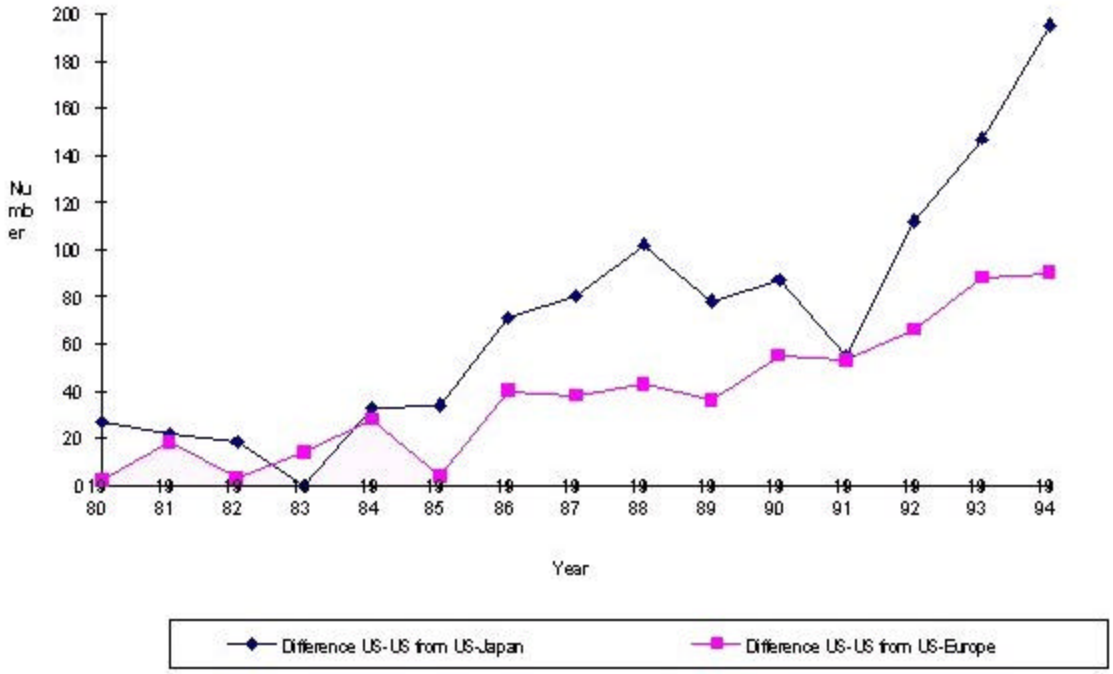
**Figure 1. Biotechnology Alliances by Country of firm origin.**

The data in **Figure 3** according to Lawton (1997) would indicate the location of structural power in the industry through both resource location and access to dominant practises. With supporting evidence for the validity of the general trends for the NASDAQ sample seen in **Table 1**, a key observation is that none of the sampled firms currently undertook strategic partnering for research and development (nor licensing of their technologies) from or to firms not residing in either the US, Japan or the EU. This remained strictly a Triad activity. In the broad sense therefore, regions, nation states and regional groupings of nation-states able to facilitate advantageous competitive conditions and factors to enterprises within their borders through the interfaces and factors described improve the prospect of developing and shaping structural and relational power attributes in global technological markets. By focusing upon policy and strategy priorities, the scope of national actors to build regional competitive advantages in the biotechnology sector can be gauged.

## Structural factor fit

The IPE perspective offers an effective way of recognising the potential 'fit' of the biotechnological sector to a

regional / national / international economic system. This moves an analysis away from a Porter style orthodox interpretation of the business environment where such methodologies view each 'level' in the system atomistically as a distinct node of operation for the actors that shape competitiveness. Thus economic policy becomes composed of a fiscal and monetary policy and business policy is both productive and corporate strategy policy derived. Whilst such an approach has value, it can nevertheless omit or fail to recognise some of the important global influences in technological sectors through which these levels merge and become rooted to other process transformations in society. This is especially important for issues of public perception, information availability, scientific trust, product labelling and safety. The development of new growth theory with its link to the systemic integration of innovation factors for endowing regions with total factor productivity, is just one outcome of this approach (Deleuze, 1988; Elliot, 1996; Metcalfe, 1998; APEC, 1998).




*Note: All technologies include Biotechnology, Information technology and New Materials.*
*Source: NSF,1996.*

**Figure 2. Prefered Origins of Collaborative Partemsin all Technologies for the USA (1980-1994)**

The importance of looking beyond the traditional Porter business environment factors, to a more systemic perspective, that encompasses both primary (structural and relational) and secondary power factors, is highlighted by Daza (1998) for example, in a review of the United Nations University (UNU) / BIOLAC initiative in Latin America. This identified gender and ideology as important issues shaping regional activity in biotechnological programmes. Similarly, DaSilva and Taylor (1998) outline a series of socio-political factors that shape the effectiveness of biotechnological development programmes in the Caribbean and other Developing Countries (DCs). Furthermore, both the NSF (1998a) and MITI (1998) review of current (1997) Japanese R & D policy has identified that key cultural changes are needed in perceptions of work and values maintained by that society in order to sustain its present competitive positioning across the technological industries (Dorebjee et al. 1998)[iv]. Rothenberg and Macer (1995) for example highlights evidence of the public perceptions of the first marketed biotechnology products in the US (Monsanto's recombinant bovine growth hormone (*rbST*) and Calgene's *Flavr Svar* tomato), which highlighted marked differences between stated behaviour and actual buying behaviour when purchasing these products. Such issues tend to be sidelined in academic mainstream strategy literature and indeed in biotechnology firm market operations (Commandeur et al. 1996). Whilst for example, the links between globalisation and firm / nation-state economic performance are aptly explored by Archibugi and Michie (1997), the authors fail to mention the development of the interaction between regions, nation-states and regional groupings of nation-states from an explicit power perspective. The development of an EU Biosafety Regulation has been problematic because of different national perceptions of the nature of risk in the first instance. Secondly, secondary effects arising

from biotechnological products interacting with the environment are not considered as relevant for decision making in the formulation of such a regulation.

Yet, this is an issue which has long been a component in debates over Europe's technological and competitive position *vis-a-vis* US and Japanese rivals (Wyatt-Walter, 1995) and which is argued here, is fundamental to the comparative performances of such firms. In essence, the conflict between national technology policy and firms in industries that are highly internationalized and in some cases globalized, is a frequent point of political discussion. Yet despite obvious policy overtones of recurrent attempts to manipulate this environment to the advancement of national economies, a firm based analysis remains primarily driven by economic viability and political legitimacy rather than by a consideration of the operation of power in such policies or through such technologies and practises. This results in oversights and arrogance in terms of what is acceptable to those markets.

Knowledge is key to our understanding of the potential for any policy to promote and sustain firm competitiveness, as well as the manner of its integration into policy development (Campanella, 1995; Metcalfe, 1998). There may therefore be a better 'fit' between the demands of the biotechnology industry and its ready acceptance for certain societies than others. This 'fit' arguably begins with those historically accumulated biotechnological resources and for which the European states possessed an early advantage. It may also be driven by societal concerns, such as an ageing population, particular predominant diseases and regional and geographical needs of food shortages, that by accident rather than design, engender the accumulation and development of certain knowledge bases and skills to a given territory.

Examples of this fit and duality of purpose for biotechnology activities, can be found with the EU's Pacific Regional Agricultural Programme (PRAP) which serves both competence development in the Pacific region as well as strategic policy objectives of the EU (**Case 1**). A further example would be the reciprocity role and function of USAID in biotechnological activities (NSTC, 1999) and the shape and development of EU programmes to ACP and CEE states (**Case 2**). With shortening product lifetimes, developing countries (DC) markets become increasingly attractive as they are under served domestically (Powell and Pearson, 1995) such as the International Development Research Centre of Canada's (IRDC) development of the CamBioTec initiative (Verastegui, 1999). Finally, the emulation of EU Directives on the containment and use of genetically modified organisms and patent protection systems in the Central and East European States (CEES), through combinations of trade and international organisation pressures, further change the shape of those markets to be more receptive and enforceable under preferred developed country parameters (EFB, 1999).

### Case 1

Operational since 1990, this programme comprises a number of projects based in the eight ACP countries of the *Lomé* convention. The Caribbean countries had, through UNESCO's Microbial Resources Centre (MIRCEN) network, the Caribbean Development Bank, the Latin American Energy Organization (OLADE), South Pacific Commission's (SPC) plant protection service and the development of a regional strategy devised in 1988[v], recognised traditional strengths in microbial biotechnological practises including:

- Biodigester designs
- Fermentation
- Bioremediation
- Tissue Culture

These are key issues being developed by the PRAP programme (currently in Phase II[vi]). Phase I sought to increase the regional facilities and capacities (infrastructural concerns) whilst the current focus is upon developing national capabilities, ostensibly via training and education. Tissue culturing has been identified within the global biotechnology sector as a prime focus for its continued development in Japan (STA, 1997), India, The Philippines and Australia (BioAsia Monitor, 1998). Maintaining access to such potentially crucial knowledge is arguably a major consequence of this initiative for EU firms. Furthermore, both Vietnam, the Philippines and China are engaged in funding and despatching scientists to projects initially operated by PRAP solely for regional institutions.

Daza (1998) also notes that apart from EU sponsoring interests in programmes like PRAP with potentially structural intentions and other party interest as noted previously, a third source of relational power has emerged in such areas which possess considerable biodiversity, yet are just gaining the skills to be able to utilize and protect this natural regional heritage. He describes this as a wider regional interest, or a South-South development.

Whilst the UN originally created the BIOLAC programme for Biotechnological Development in Latin America (narrowly geographically defined), both Canada and Peru have become involved in the initiative (and contributed funding), with the intent on gaining knowledge from the programme's three main objectives: diagnostics, vaccines, plant genetics and microorganisms of industrial interest. Nevertheless, their review of the origins of participants and the results of the programme support a primarily regional perspective, with South-South networks of collaboration and information exchange dominating. Links with the developed countries, such as the USA are maintained but not intensively.

### Case 2

The Commission communication on industrial policy in 1994 (COM (94) 319 Final) is informative of the development of intentional and unintentional industrial structural power. For example, extensive reference is made to building and developing increased economic ties with the ACP (African Caribbean Pacific States) and CEE (Central East European) states. Indeed in the CEE states, pressure has already been exerted upon the cheaper manufacturers in those countries to limit production so as to not unduly affect the prevailing economic situation with the EU. The lever for this has been future industrial co-operation and the transfer of technology including biotechnology[vii]. The focus of ACP and CEE states for EU industrial policy measures is primarily driven by the emergence of growing markets that can be effectively captured by EU and European producers and be guided to use European standards, where control of the IPR has been recognised as an important aspect in shaping the knowledge structure (see for example, APEC, 1998)[viii]. In those markets where European industries face strong competitive forces that can affect both employment and production levels, political intervention has been frequently employed on a bilateral basis to safeguard the European position (in semiconductors and automobiles for example (Mason, 1994; Lawton, 1997). In other sectors, multilateral discussion has been used but often with only temporary results requiring episodic amendments (in the aeronautics, steel and audio-visual industries for example)[ix].

Continuing these themes of duality, the countries of Brazil, Chile and Argentina, which possess considerably sized markets, are making concerted efforts to increase their technological standing in the regional environment, sometimes in opposition to WTO/TRIPs preferred practises to protect indigenous resources (Seiler, 1998). Private sector funding in these countries, has also increased considerably over the 1990s[x] with Brazil leading the regional way in developing technology transfer initiatives that target information technology, biotechnology and informatics that ensure internationally competitive standards and quality (OTP, 1997).

Galhardi's (1994) study of new biotechnology firms (NBF) in Brazil, further supports this perspective. Indigenous firms there are proactive in using the research knowledge and skills of regional universities, other indigenous firms and foreign firms. However, the key difference between the NBF in this DC and those examined for the US or other developed country (DVC), is found to be in their respective knowledge roles. In the latter, the NBF can operate as a 'research boutique' (Owain, 1998) where the larger transnational firm can use it to source new knowledge, insight and skills. The review of NASDAQ research employees later, stresses the greater NBF focus upon individuals with these skills over the larger more established firm. In the DC, the situation is reversed. The indigenous NBF sources the large firm for technology and knowledge. Flow of knowledge and technology therefore changes direction and hence the ability of the DVC transnational to shape the biotechnological sector is enhanced through a greater ability to manipulate that knowledge. This developing country focus activity, is in opposition to the perceived developed country focus of such firms (EFB, 1996).

Overall, these considerations of the knowledge role and access to relevant resources, place strategic limits on the choices available to the managers of a biotechnological business in the DVC and DC. The organisational structure and business activity of that company is constrained but in different ways. For the DC biotechnological firm, technology acquisition (rather than generation) brings codified knowledge to the DC industry, whilst activities pioneered by the state domestically (broadly defined) and with other governments, increase the overall stock of human capital available and the impact of TFP for the sector within that region. The DVC and DC firm also tend to face opposing customer demands and perceptions – with the choice between quality or price of a genetically modified product being superseded by availability of a product. The knowledge creating companies (using Nonaka's (1996) terminology) are very different between the DC and the DVC.

## A broadening understanding

The importance of these regional differences have come to the attention of international business theorists. Casson (1991), Wyatt-Walter (1995) and Dunning (1997) suggest eclectic approaches to understanding the international business are appropriate precisely because of the accidental and constructed factor advantages in differing regions. By considering sector dynamics and key competitive issues that can be most effectively addressed by the firm and public policy, there can be a positive or negative change in human capital and TFP influences. This will, through the new growth theory perspective for example, implicitly include consideration of specific socio-economic local, regional and national dimensions that shape citizen and business people's activities, behaviours and perceptions. In this fashion, non-economic factors become a key consideration of sustainable competitive advantage. As a result, current orthodox international strategic arguments based around competition and adversarial activities are limited in their perspective and relevance (Burton, 1999). This merging of concepts is evidenced by policymakers adopting a more mixed strategic approach to the development and implementation of biotechnological policies and is one directly supported by the use of the Lawton IPE framework.

## The biotechnology sector's industrial structure

In a sector of the economy that is reliant upon new knowledge and basic research, long industrial lead times and investment requirements are further factors shaping the firm's structural position. The poor profit performance of the majority of the sector's firms is highlighted by the sampled NASDAQ firms, where only 8 recorded a profit in

1998 (averaging 20.98m$). This was an increase though from the same sample's performance in 1997, where only 5 firms recorded a profit (averaging 11.6m$). The most spectacular profit loss was recorded by AXYS Pharmaceuticals of $203m$. This is partially explained by the fact that this it is a new company founded in 1998, investing heavily in research and development. When the age of the sampled firm is compared with the profit level, **Table 2** is obtained. **Figure 3** plots these values.

**Table 2. Performance characteristics by age group of sampled firms**

| Age Group | *Number of firms* | Average turnover (1998) m$ | Average Profit (1998) m$ |
|---|---|---|---|
| | | | |
| 1 to 4 | 3.00 | 20.80 | -71.52 |
| 5 to 9 | 11.00 | 38.39 | -11.18 |
| 10 to 14 | 9.00 | 17.06 | -13.37 |
| 15 to 19 | 8.00 | 76.66 | -1.115 |

*Note: 3 firms sampled were over 20 years old and are not included in the above table.*

**Table 3. Average R & D reinvestment of sampled firms according to age grouping**

| Age Group | Average R & D reinvestment (% -1998) |
|---|---|
| | |
| 1 to 4 | 68.08 |
| 5 to 9 | 199.72 |
| 10 to 14 | 255.49 |
| 15 to 19 | 150.29 |

**Table 3** indicates the degree of research reinvestment by the sampled firms as a percentage of firm turnover in 1998. **Figure 4** plots this relationship.

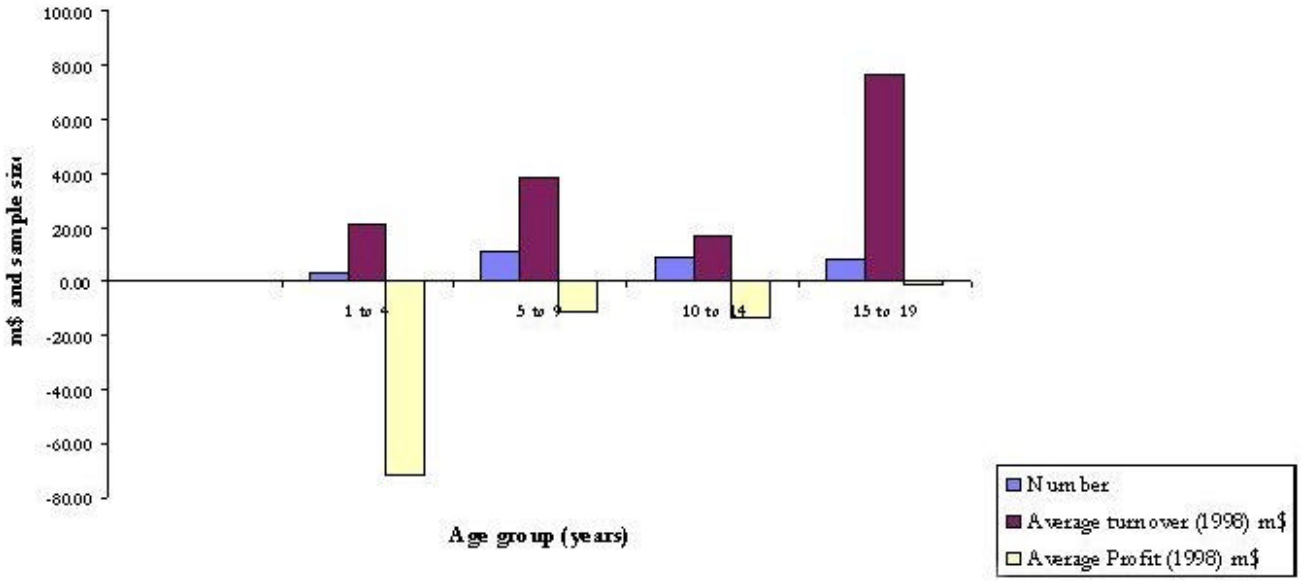



**Figure 3. Preformance charcteristics of sampled NASDAQ firms (1 - 20 years old)**


**Figure 4. Performance characteristics of sampled firms**

The 1997 report on Science and Technology Indicators from the National Institute of Science and Technology Policy (NISTEP, 1997) in Japan, indicates for example, that the drugs and medicines industry maintains the highest R & D expenditure per sales ratio of any industry sector, with eight per cent minimum reinvestment. Of the sampled NASDAQ firms though, this reinvestment figure is considerably higher (see **Table 3**).

The biotechnological business is, unlike IT for example, constrained and in some instances promoted, by regulatory frameworks established for public health reasons, which vary country to country. Notably this includes in the biopharmaceutical sector the role of the state as a significant consumer (Powell and Pearson, 1995; IPTS, 1997). Welles (1999) describes these constraints as:

- Clinical failure
- Clinical success but market failure
- Delays in delivering products/research

Whilst market failure is a risk of all businesses, a three tier clinical market demand system produces market imperfections. With the doctor prescribing the drug, the patient taking it and the insurance company meeting the cost, neither the final demand nor the payment is controlled by the consumer. This mismatch between market supply and demand forces is further exacerbated by the nature of drug manufacture and clinical trials.

Preclinical laboratory tests are required for new drugs and which must support an application for clinical trials that have three phases. Each phase of the trials is subject to rigorous regulatory control. Phase I trials involve assessing safety aspects with healthy humans. Phase II involves administering the drug to a controlled limited patient population, whilst phase III expands this limited trial to a broader population in different geographic sites. Whilst Phase I and Phase II trials can often be supported internally by the company, Phase III trials require substantial territorial/global support and manufacturing capabilities and as only a limited number of firms are able to supply such resources, contract manufacturing becomes an additional key competitive factor in drug development (IPTS, 1997; Werner, 1998). Indeed, these essential supporting activities include corollary research programs of collaborative activities, information management and quality assurance (Werner, 1998). Only latterly have programmes to increase the dialogue between the consumer, scientist and biotechnology firm been addended to such activities (EFB, 1997; EFB, 1998; Joint Economic Committee, 1999).

With most small biotechnology firms limited in their potential to diversify product ranges, given capital development costs needed for state-of-the-art facilities, ethical concerns over testing (and viable alternatives), pressures upon salaries and the costs of purification of a biotechnology product (Powell and Pearson, 1995), most of them, can only carry as few as a handful of separate products lines (Werner, 1998).

Furthermore for an EU oriented biotechnology firm, coping with 15 different public health care policies and regulatory requirements, only adds to the complexity and potential difficulty of generating new products (Hayward, 1998). A supportive institutional environment that readily works with the firm on clinical testing issues through provision of those relevant power factors described, endows that firm with a distinct competitive advantage (Thumm, 1999; Wolf, 1999). For example, Singapore is recognised within the sector, as being able to supply all the necessary resources for biotechnology clinical trials, which in conjunction with an aggressive funding regime ($2b devoted to biotechnological R & D in the current National Technology

Plan), enables indigenous firms to rapidly gain market share through exchanges of those resource factors with foreign firms (BioAsia Monitor, 1998). In contrast, the Federal Drug Authority (FDA) in the US whilst remaining a significant structural gatekeeper to the US market, has experienced budget increases that have largely been eaten up by inflation and reducing its capacity to promote its preferred standards and practises (Wechsler, 1998).

## Biotechnology firm types

Welles (1999) further argues that biotechnology firms are a mix of three types of enterprise. These three enterprise types necessitate different policy measures. Implicitly therefore, the structure of the industry demands the mixed strategic approach because of these firm types as well as through the different locational factor differences already discussed.

The first generation of biotechnology firm (type I) is an integrated research and development (R & D) venture, concerned with in house research, funding, marketing and production. The second generation biotechnology firm (type II) operates as a drug discovery company, more concerned with bio-prospecting to find a new competitive advantage than leaving all research to an in-house team (Kupper, 1999). Finally, the third generation of biotechnology firm (type III) is the drug development company, which develops existing drug and biotechnology knowledge. It might therefore be expected that this type of biotechnology firm would foster more extensive collaborative agreements (such as technology licensing) to develop its product portfolio, whilst the type I firm has slightly less of an incentive to foster such functionally oriented collaborative activities, due to a potential dilution of in house capabilities. Such type III firm strategies generally however, are not necessarily just the remit of small firms. Powell and Pearson (1995) give the example of Hoffman la Roche & Co. which introduced and marketed an antibiotic, Rocephin. This had already been developed but not previously marketed.

The type III biotechnology firm, has significantly different requirements and needs from their business environment. With reduced in house capital needs, less overt distant knowledge appropriability problems through bioprospecting and outsourced research activities, their main policy support reliance is upon infrastructural routes for knowledge dissemination, communication and co-operation. Delays arising from clinically rejected or market driven causes are less of a problem for a company that pursues many different product lines. Type I or II firms with substantial resources can obviate some of their difficulties by using type III firms and/or start up ventures as the technology transfer conduits mentioned earlier (Powell and Pearson, 1995; BioAsia Monitor, 1998)[xi].

Finally, the type III firm is not concerned with direct in house, nor capital intensive research, but directs its attention to the already abundant knowledge that has been made available through existing research but which has not yet been commercially developed. Such firms tend to maintain extensive links with University R & D staff whilst operating as a virtual entity and are able to be more proactive in adjusting to changing consumer perceptions and regulatory environments (the US modified its Biosafety Regulation 4 times to 1995 alone (Commandeur, 1996)). This has less capital requirements, facilitates a greater product range and hence has less associated market risk for the firm. Typically, this has been the strategy pursued by EU biotechnology international companies (Hayward, 1998). The research and skill emphasis changes from cutting edge new-to-the-world knowledge and speed of research, to methodical examination and insight. This demands highly skilled individuals with extensive experience and an ability to recognise potential and as such, these firms emerge and are dominant in developed countries (DC) with significant competitive human resource strengths. Evidence for these skills may be found by examining the R & D staff composition of firm human resources.

Applying the Welles (1999) classification table to the sampled NASDAQ firms, reveals a generally good fit, although several of the companies reviewed are in the process of moving between firm types (through the development of in house manufacturing facilities for example). Moreover, a handful of firms are developing both in house basic research skills in conjunction with a manufacturing presence (a type III to II to I firm).

**Table 4. Comparison of biotechnology firm types and number of collaborative agreements**

| Firm type | Total number of collaborative agreements | Average number of collaborative agreements by firm type | Number in sampled firms classified as this type |
|---|---|---|---|
| I | 58 | 4.1 | 14 |
| II to I | 37 | 5.3 | 7 |
| II | 81 | 4.5 | 18 |
| III to II | 13 | 13 | 1 |
| III | 50 | 6.3 | 8 |
| III to II to I | 3 | 1.5 | 2 |

Ignoring the transitional firm types (due to insufficient data), the above table suggests that the type III firm is in fact more collaboratively active, whilst type I firms are the least collaboratively active as was suggested earlier.

In addition, 52% of the sampled NASDAQ firms provided information on human resource issues, although only 37% were EU defined SMEs (from the employment perspective (CEC, 1998)). Of that 37%, the average number of staff employed was 100. The range of staff employed for all the sampled NASDAQ firms however, ranged from 6 to 2100 employees. 11 firms disclosed the proportion of staff that were researcher focused (23% of total) and of that sample, 73% were SMEs. The average number of research staff in those SMEs was 58 employees. Therefore for the SMEs sampled, 58% of their staff were on average, research workers. When all the sampled firms are reconsidered that provided staff research information, the average proportion falls to 27%. A specific focus on research highlights an average 18% of the workforce for the biotechnology firms are doctorates. The comparative importance of research workers to the smaller firm is clear from the sample.

The importance of these human resource and knowledge factors through collaboration activities for sustaining competitive strength is highlighted by the differences between the types of biotechnology company operating in developed (DC) and developing countries (DVC). Solleiro and Castañon (1999) in a review of the strategies of successful Latin American biotechnological firms, stress the importance of a suitable and embedded infrastructural environment to foster the different types of company (type I, II and III). Type III firms though, can successfully operate in Latin America through a mixture of portfolio investments and developed commercial partnerships with global biotechnological companies under the rubric of contract manufacturing and distribution as production competitive factors. From a holistic policy perspective, the type I firm is heavily dependent upon three dimensions of the support environment:

- Availability of capital
- Availability of skills and knowledge (including databases, journals, access to talented individuals etc)
- Clinical and healthcare requirements (for biopharmaceutical ventures) and market acceptability (for food and agro based products)

This places demands upon policy measures in terms of financial and knowledge support whilst operating a 'friendly' clinical environment. The UK, Canada and Australia for example are currently investigating methods of economically evaluating new drugs for their welfare services amongst broader healthcare reforms (IPTS, 1997), whilst the German clinical trials environment is argued to be driving investment out of the country and to the US (Slater, 1996; Slater, 1998). In the US, the Prescription Drug User Free Act (PDUFA) is using revenues to finance drug evaluations and increase the rate and acceptance of new drugs (Wechsler, 1998).

In the Japanese market, the regulatory environment for pharmaceutical products is intensive through internal competition (through approximately 1500 domestic firms) and mandates that the prices for drugs must be reduced every two years, creating an incentive for new product development by necessarily ensuring short product lifetimes (BioAsia Monitor, 1998). Indeed, very little export income is generated by these firms, which serve primarily the second largest domestic market in the world (see **Table 5**). Submission of new drug applications (NDA) by foreign firms have been greater than domestic firms since 1990 in Japan, as EU and US companies begin to sell directly to the market (Kawamura, 1998).

**Table 5. Japan's technology trade (1995- 100m Yen)**

| Sector | Exports | Imports |
|---|---|---|
| Motor vehicles | 1591 | 75 |
| Industrial chemicals and chemical fibres | 267 | 166 |
| Iron and steel manufacturing | 169 | 42 |
| Drugs and medicines | 367 | 367 |
| Communications and electronics | 1528 | 1734 |
| Other Industries | 1699 | 1533 |
| All industries | 5621 | 3917 |

*Source: NISTEP, 1997.*

In accordance with the 'fit' argument that extends to secondary market factors, certain types of knowledge and the structural factors, will be more directly appropriable by host nation subsidiaries and firms than others (Metcalfe, 1998; Welles, 1999). For example, EU orchestrated technological support mechanisms are dependent upon information and knowledge flows between international businesses and nation-states that rely upon the environmental background of the individuals responsible for encoding and decoding that knowledge and information. Hence there is a suggestion of an evolutionary flow between the types of biotechnology firm described

previously (at least in the sense of market maturity) (Buckley and Casson, 1976 quoted by Kogut and Zander, 1993).

At first glance, the composite nature of the EU suggests that these differing regional and national environment backgrounds would be a particular difficulty not found in the other global biotechnological nodes of potential structural and relational power which are more homogenous, such as the USA and the Pacific Rim. This is in fact a common focus of the most recent review of the EU's Framework Programme (CEC, 1997a). However, the metamorphosis of policy to embrace multiple objectives, encompass increased numbers of actors and expansion into educational and entrepreneurial arenas, recognises the need for a common European frame of reference and the creation of a shared awareness. It can also provide a diverse mix of existing (historical) biotechnological competences, which from a firm competence perspective, helps underpin sustainable competitive advantage. The very complexity of the EU biotechnology market may therefore be a source of competitive advantage.

For type II biotechnology firms more concerned with gaining a competitive advantage by casting a wide knowledge net, rather than the narrow one with type I firms, capital requirements whilst high, would arguably be more dependent upon prospecting 'success'. This has implications for the intellectual property regime of the host and home region/state, the meaning of a common 'natural heritage' and 'preservation of biodiversity' (DaSilva and Taylor, 1998). The UN Convention on Biological Diversity's (operational from December 1993) discussion on the ownership of genetic resources with a sovereignty caveat and the slow development of the EU Directive on Protection of Biotechnological Inventions from 1988[xii] (EFB, 1996; Thumm, 1999), illustrate that existing national and regional patent rights are difficult to enforce and validate[xiii], yet are viewed as being a requirement for sustainable competitiveness. This viewpoint is not wholly supported as the mix of soft perceptional issues and hard patent / intellectual property issues between the actors of the IPE model with questions of the welfare necessity of biotechnological products, continues to hamper universal agreement on progression with biodiversity, indigenous and community rights and fair market protection (Commandeur, 1996; Commandeur et al. 1996; Seiler, 1998; Ghijsen, 1999; Nijar, 1999).

Both type II and type III firms face significant purification problems with new products where these downstream separation costs can be the most expensive stage of new product development (NPD). It is therefore no surprise that bioprocessing is a key element in all Triad biotechnological support policies (NSTC, 1999) (see **Table 7**). Equally, the development of supporting bioinformatics is a prerequisite of a competitive developing biotechnological industry given its dependence upon the volumes of data generated. Gaining additional insight and knowledge in these areas would constitute a significant source of competitive advantage.

With a global market estimated to be around $100b in 2000, roughly equally divided amongst the Triad regions (CEC, 1999), the policy direction of national R & D funds in these regions presents an interesting contrast. As **Table 6** highlights, there have been opposite spending directions in the US and Japan.

**Table 6. Comparative Triad BERD**

| Region | Gross Domestic Expenditure on R & D (billions of local currency units) (1995) | Percentage of R & D expenditure by sector of performance(1995) | |
|---|---|---|---|
| | | Government Funding | BERD expenditure(1995) |
| US | 178.6 | 9.2(-) | 72.0(=) |
| China | 28.6 | 44(-) | 31.9(+) |
| Korea | 9,440.6 | 3.5(=) | 73.1(+) |
| Thailand | Not available | 48.8(-) | 7.3(+) |
| Japan | 0.6 | 10.2(+) | 71.2(-) |

*Source: APEC, 1998*
*Key: -, + and = denote how the share of R & D funding by the actor has changed since 1990.*

In the biotechnology sector, Japan is reorientating its spending priorities so as to reflect particular country characteristics. On the basis of the importance of knowledge in technological industries, especially new to the world knowledge in the biotechnological sector, government investment is increasing in basic R & D initiatives and facility development (NISTEP, 1997). The importance of knowledge in the economy of a DVC mandates Japan addressing this particular problem so as to ensure TFP benefits in the future. The argument is largely reversed for other Asian economies that lack the substantial and integrated industrial base of Japan and are seeking to

develop this as an outlet for the previous intensive investment in basic R & D and human capital issues since the mid 1980's. The refocus of Japanese biotechnological competitiveness is further emphasised by the importance of Health as the largest academic field in terms of the number of R & D scientists/engineers within the natural sciences (NISTEP, 1997). Further supporting the 'fit' argument, the most numerous academic societies in 1995 were in the medical and humanities areas in Japan. It is therefore no surprise to note that Japan also has a large share of scientific papers in pharmacology, much higher for example than other emerging technological commercial markets such as earth and environmental science (NISTEP, 1997).

**Table 7. Biotechnology and R & D profile of major technological nations in the world**

| Country | GDP | Total Trade Balance | R & D Personnel[a] | R & D funding (% of GDP by sector) | | | Public and Private Research Priority Areas (1995 unless otherwise stated) |
|---|---|---|---|---|---|---|---|
| | (mECU) | (mECU) | | BERD[1] | Gover n-ment | HE | |
| Belgium | 170816 | 8085 | 44.2 | 1.09 | 0.06 | 0.44 | IT, biotechnology, aerospace, new materials, telecommunications, oceanography |
| Denmark | 119237 | 4823 | 41.4 | 0.85[b] | 0.42[b] | 0.42[b] | Drugs and Medicine, machinery, SMEs, Biotechnology, IT, cancer research, new materials, environment |
| Germany | 1467958 | 51623 | 23[m] | 1.51 | 0.34 | 0.43 | Preventative research (environment, health, climate), SME Innovation, IT, Biotechnology, materials research, transport and energy[d] |
| Greece | 74716 | -12375 | 15.4 | 0.12[c] | 0.13 | 0.22 | Infrastructure development, social and human sciences, IT, biotechnology |
| Spain | 437331 | -8876 | 24.6 | 0.37 | 0.17 | 0.25 | Information and production technologies, natural resources and agro-industry |
| France | 1032681 | 9277 | 14.6[m] | 1.44 | 0.49 | 0.38 | Very large public funded institutions, Basic research programmes (AIDS, Human Genome analysis), IT, HDTV, Aeronautics[e] |
| Ireland | 56223 | 10922 | 57.6 | 0.99 | 0.14 | 0.27 | Biotechnology, engineering, new materials, IT |
| Italy | 929581 | 34690 | 30.6 | 0.56 | 0.22 | 0.26 | Biotechnology, chemicals, IT, new materials, fusion telecommunications |
| Netherlands | 263988 | 10137 | 39.7 | 1.09 | 0.53[b] | 0.18[b] | General industrial competitiveness, technology diffusion and knowledge dissemination |
| Austria | 146341 | -8336 | 24.0 | 0.80[b] | 0.4[b] | 0.4[b] | - |
| Portugal | 59424 | -8099 | 12.4 | 0.12 | 0.16 | 0.20 | Education and basic research, biotechnology, robotics, materials science and marine science |
| Finland | 111920 | 7640 | 54.0 | 1.50 | 0.41 | 0.46 | - |
| Sweden | 191377 | 14160 | 56.0 | 2.68 | 0.13 | 0.63 | Telecommunications, pharmaceuticals |
| UK | 870798 | -23821 | 14.8[m] | 1.35 | 0.30 | 0.39 | Industry-academia linkages, SMEs, bioprocessing and biotechnology, optics, lasers, aerospace |
| Norway | - | - | - | 0.84[b] | 0.53[b] | 0.53[b] | IT, biotechnology, new materials, |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | aqua culture, oil and gas technology |
| Switzerland | - | - | 45.0 | - | 2.60[f] | - | - |
| Japan | 1653000[h] | 27669[n] | 80.0[h] | 2.37[g] | 0.40[g] | 0.23[g] | Knowledge advancement, energy, drugs and medicines, computers, electrical machinery, chemical products, transportation[i] |
| USA | 4173000[h] | -525.1[n] | (96.3[q])74.3[h] | - | - | - | Defence, health, IT, biotechnology, new materials |
| Singapore | 67000[k] | - | - | 0.49 | 0.21[i] | 0.19 | National Technology Plan (1995-2000) with a $2b budget including biotechnology |
| Taiwan | 248000[k] | - | - | 1.20 | 0.29[i] | 0.20 | 1982 Biotech focus in policy. Funding delivered through universities, RTOs and central none profit organisations (basic research emphasised). Antibiotics, rDNA engineering, enzyme development, food colours and organic dyes |
| South Korea | 344094[k] | 5543[n] | - | 1.77[p] | 0.04[i] | 0.09 | HAN Projects, plus sectoral initiatives in aeronautics and the space sector |
| China | 548818[k] | - | - | 0.18 | 0.33[j] | 0.19 | Basic research, biotechnology, life sciences (biology and medicine), Hazard research (weather), space research, developing IT (to be world class by year 2000) |

***Notes and Sources:***
*[1]Figures include private non profit R & D funds.*
*[a] Per 10,000 persons in the labour force (1991 figures) (NSF,1995)*
*[b] 1993 figures (NSF,1995).*
*[c] 1992 figures (NSF,1995)*
*[d] Traditional German strengths in electronics, automobiles and machinery are being gradually eliminated due to a susceptibility to price competition derived from labour costs. Biotechnology and IT are being heavily invested in. As are the development of links between HE Research Institutes and entrepreneurs.*
*[e]The network of French research centres comprises INSERM, CEA, INRA, INRIA, CNES, IFREMER.*
*[f]Total R & D invested as a % of GDP.*
*[g]1997 figures (STA, 1997).14% of this sum in total was directed at basic research, 24% for applied research and 62% for developmental research.*
*[h]1994 figures (NSF, 1998b). For Japan, 1995 figures place this level lower at 67.3 (NISTEP, 1997).*
*[i]This has been accompanied by a decline in automotive industries, chemicals and the basic metals industry of iron and steel. (NSF, 1998b).*
*jFigures for China have only been produced since 1990 (All figures for 1990).*
*[k](UN,1997). Information gathered from http://www.un.org*
*[m](BMBF, 1997) and (NISTEP, 1997) for 1993 figures.*
*[n] 1996 figures (IMF, 1997). The exchange rate conversion used to ECU from $ at 1$=1.27ECU.*
*[p] This will rise to a total of 4% of GDP by the year 2000 (OECD, 1996)*
*[q] 1995 figures by NISTEP(1997). These are still in line with the proportional figure of 97 given by 1991 figures (CEC, 1998).*

*Unless otherwise stated, the source for the data was the New Cronos Database (11/02/98) taken from the EU Europa Server at http://www.europe.eu.int/en/comm/eurostat/indic/indic92.htm. In addition to the above, see also http://www.ics.forth.gr (Greece Foundation for Research and Technology).*

The STA (1998) report on Globalization and the Japanese economy stresses these themes by acknowledging the broad economic function served by near and far markets for Japanese firms. The former, largely in the proximity of Japan, served to reduce production costs whilst developing a market base (which has become more important as these countries have industrialized)[xiv], whilst the latter (far) market is home to both consumer and knowledge, with in-particular the protection of that knowledge. These factors are also regularly identified as key issues for foreign firms (non domiciled) to collaborate with other home firms (Dalton and Serapio, 1995; Trott, 1998). Arguably therefore, the regional dynamic was more important for securing firm competitiveness in host countries. Furthermore, NISTEP (1997) identifies that 90% of foreign researchers entering Japan in 1995 came from other Asian countries and were study and training focused. From the Japanese perspective, the level of researchers leaving for DC's has been falling since 1993, yet the number of individuals being despatched for cultural reasons to DCs

has been increasing, especially to Central and South America. Arguably this suggests that access to relevant knowledge, as with **Case 1** and **2**, requires the development of an understanding of both the market and culture within that environment.

**Table 8** outlines some of the different incentive schemes established within national boundaries and from an EU perspective, whilst table 9 reviews the explicit EU biotechnology programmes. Importantly the DVCs tend to maintain control over entry to their market where despite no explicit limits on access to any firm to any EU initiative, implicit constraints do apply in US, EU and Japanese initiatives. For the exploitation of knowledge, initiatives excluded non domestic/domiciled firms unless mutual benefit could be assured through knowledge exchanges and/or manufacture in the home market. However where industries are identified as being strategic, including the enabling technologies in which a case by case basis applied unless specific bilateral arrangements had been previously engineered. Obvious fears over transferring knowledge, intellectual property and competitive advantage to non-domestic firms drives these constraints. There is also a recognised shift in attitudes between DVC and DC firms however, where less knowledge based concerns were evident for firms from DVC except in the strategically identified sectors. When programmes were strictly confined to domestic firms only, notably in the strategic sectors including biotechnology, three clear situations can be defined by reviewing the construction of the support programme. They revolve around a pure internal focus (in this case either nation-state or regional grouping), an expansionist focus (where non home domiciled firms are allowed access potentially subject to reciprocity, transparency and exploitation) and a globally focused initiative which seeks from the start to incorporate all leading industrial actors in an initiative. Such programmes for example would aim to develop standards for an industry.

**Table 8. Matrix of different regionally focused initiatives and objectives: IT example**

| Collaborative Focus | Objectives | Activity |
|---|---|---|
| | | |
| Internal to the country (domestic firms) | Developing internal resources to industry competitive level | Consolidation (examples include VLSI, EUREKA, early SEMATECH, JESSI, $ES^2$) |
| External to the country(all firms) | New to the domestic group knowledge and skills | Expansion (examples include ESPRIT phase III/IV, late SEMATECH) |
| Globally focused | Standard setting | Standard setting |

*Key: VLSI – The Japanese semiconductor programme of the 1980s - the very large scale initiative, EUREKA – French inspired pan European technological collaborative programme (1985), SEMATECH – US semiconductor research consortium- semiconductor manufacturing and technology institute, JESSI – The Joint European Sub micron Silicon Initiative (Siemens, Phillips, GEC, SGS Thomson, STET), $ES^2$ – Joint venture of Olivetti, Bull, Phillips, GEC, Siemens in the early 1980s (matched by $US^2$ in the US), ESPRIT – The European Strategic Programme for Research in Information Technology (since 1983).*

**Table 9. Major EU Biotechnology Programmes (Shared cost and concerted actions)**

| *Programme* | Year | Objectives | *Funding* | Comments |
|---|---|---|---|---|
| Medical Health Research (MHR) | 1978-1992 | Variety of contemporary medicinal projects (over 4 consecutive programmes) | Not available | Acted as lead into the BIOMED I programme. |
| BEP (Biomolecular Engineering Programme) | 1982-1985 | Application of biotechnology to the agrofood industry and agriculture. | 15m ECU | High industry involvement |
| BIOMED I | 1990-1994 | Pharmaceuticals, occupational and environmental health, Biomedical technology, Public health, AIDS, TB, infectious diseases, cancer and cardiovascular research, | 134 mECU | Largely basic research driven. |

| | | | | |
|---|---|---|---|---|
| BIOMED II | 1994-1998 | brain research, chronic diseases and ageing, human genome research, biomedical ethics | 154 mECU[1] | Three foci – Health Care Providers Large Companies SMEs<br><br>However, industrial interest remained low. Main interests of project participants were therapeutics, diagnostics and epidemiological. |
| Biotechnology action programme (BAP) | 1985-1990 | Successor to the biomolecular engineering programme (BEP) (1982-1985). | 75 mECU | High industry involvement |
| Agro-Industrial research | 1987-1994 | Plant genetic engineering , animal production and health, forestry and fisheries and food safety amongst other issues. | 493 mECU | Low industry involvement |
| Biotechnology Research for Innovation, Development and Growth in Europe (BRIDGE) | 1990-1994 | Information infrastructure, enabling technologies, cellular biology, pre-normative research – industrially oriented. | 100 mECU | High industry involvement |
| BIOTECH I | 1992-1994 | Molecular biotechnology, cellular biotechnology, ecology and populations, horizontal activities | 189 mECU | Low industry involvement |
| Agro-Industrial Research and Fisheries (AIR) | 1994-1998 | Follow up to the Agro-Industrial research programme | 684 mECU | Medium industrial involvement |
| BIOTECH II | 1994-1998 | Cell factories, immunology, infrastructures, genome analysis, plant and animal biotechnology, cell communication, structural biology, pre-normative research | 552 mECU | High industry involvement |

[1] *First call only.*
*Source: Commandeur et al. 1996; CEC, 1997a; CEC, 1997b; CEC, 1997c; DG XII, 1998.*

## Concluding remarks

This paper has reviewed the development of the biotechnology sector, with a focus upon the specific competitive factors underpinning that market sector from an international political economy perspective. By identifying successful positioning within the industry as derived from the structural power of the company, or rather its ability to shape the industry to preferred norms of operation and practises through data such as collaborative partners, the activities of public and private policies were examined. Important secondary factors that mediate this structural capacity were also identified. This was undertaken using secondary data, insights gained from a small sample of US NASDAQ quoted biotechnology firms and comparative lessons from the IT sector.

With a focus upon the four structural power factors of knowledge, production, finance and security, the actions and preferred orientations of the actors involved in the development of the industry were examined. This interaction is the focus of the IPE diplomacy model, which was used as a guide to the dominant inter-relationships between governance levels, actors and other bodies. All four factors are stressed within the sector, from security issues with biodiversity, production with purification techniques, finance with drug development costs and knowledge through TRIPs / *sui generis* protection systems, as underpinning all these factors especially for the smaller biotechnology firm in the developed country. The strong triad relationship was evident in this sector, especially in terms of the direction and dominance of developed country knowledge flows. Indeed, the strong structural position of firms from such regions, was evidenced in the manner in which they construct agreements and support programmes for non-triad regions and how access to national markets by other globally competitive firms, is carefully managed.

Using the IPE framework however, also illustrated the relevance of non traditional strategic issues for such firms, including gender, ideology, specific locational concerns, perceptions, biosafety and intellectual property systems, that have ensured the development of resource bases in varying regions (through different knowledge and practises)

that are also driving the development of the sector. These broader strategy and policy concerns have helped certain parts of the world obtain a better fit between the needs of the biotechnology sector and what the local environment can supply.

In conclusion, the policy support environment for biotechnology firms, is a complex mix of factors, some of which are part of the national identity, whilst others are being actively constructed by dominant actors. This paper has highlighted the validity of viewing the sector as comprised of at least three basic firm types, with different knowledge roles depending upon the location of the firm. Adopting an IPE perspective allows greater understanding to be made of this complexity.

## References

Adam, M. (1997). Entrepreneurialism and the European Commission. Nature 15:9-12.

Archibugi, D. and Michie, J. (1997). The Globalization of technology: A new taxonomy. In: Technology, globalization and economic performance. D. Archibugi and J. Michie (eds.), pp.172-197. Cambridge University Press.

Asia-Pacific Economic Co-operation (APEC) (1998). 1998 APEC Economic outlook: Economic trends and prospects in the APEC Region, Economic Committee Asia-Pacific Economic Co-operation, November.

Assouline, G. (1996). European industry strategies in biotechnology. Biotechnology and Development Monitor 26:10-12.

Barnum, A. (1993, July 10). FBI probes spying on biotech firms. The San Diego Union Tribune, pp. C-1.

Berliner, U. (1999, February 16). Venture capital investment here strong despite dip. San Diego Union-Tribune, pp.C-1.

BioAsia Monitor (1998). General profile of biotechnology activities in Asia. Available on the Web: http://www.biocompass.com.

Bundesminister fur Bildung Wissenschaft, Forschung und Technologie (BMB+F) (1997). Biotechnology in Germany, 176 pp.

Burton, J. (1999). The conjunction of competition and collaboration in international business. In: The organization of the firm: International business perspectives. R. Mudambi and M. Ricketts (eds.), pp. 102-125. Routledge, London, UK.

Campanella, M. L. (1995). The effects of globalization and turbulence on policy-making processes. In: Readings in international enterprise. J. Drew (ed.), pp. 15-25. Routledge, London, UK.

Cantley, M. (1999). The EU regulatory framework for biosafety. 3rd Annual Conference of the European Biosafety Association. Available on the Web: http://www.ebsa.be/abstracts_of_the_2nd_annual_conf.htm .

Casson, M. (1991). Global research strategy and international competitiveness. Blackwell, Oxford, 343 pp.

Cerny, P. G. (1996). What next for the nation-state? In: Globalization: Theory and practice. E. Kofman and G. Youngs (eds.), pp. 123-137. Pinter, London.

Charles, D. (1995). Support for technology in small firms in Europe's less favoured regions: Lessons from the evaluations of the EU STRIDE programme. 3rd Annual High Technology Small Firms conference. Manchester Business School, 18-19th September 1995.

Christensen, J.F. (1996). Analysing the technology base of the firm: A multidimensional resource and competence perspective. In: Towards a competence theory of the firm. N. J. Foss and C. Knudsen (eds.), pp.111-132. Routledge, London.

COM (94) 319 Final (1994). Communication from the Commission to the Council, to the European Parliament, Economic and Social Committee and the Committee of the Regions: An Industrial competitiveness policy for the European Union.

Commandeur, P. (1996). North-South America Conference on Biotechnology. Biotechnology and Development Monitor 26:20-22.

Commandeur, P., Joly, P.B., Levidow L, Tappeser B. and Terragni F. (1996). Public Debate and Regulation of Biotechnology in Europe. Biotechnology and Development Monitor 26:2-9.

Commission of the European Communities (CEC) (1999). 2nd Conference of the Biotechnology and Finance Forum. Lyon, 26th – 29th March 1999, DG XII Press Office. Available on the Web: http://europa.eu.int/comm/dg12/press/1999/pr2503en.html.

Commission of the European Communities (CEC) (1998). Revision of EU SME definitions to recommendation 96/280/EC, COM(26) 1998.

Commission of the European Communities (CEC) (1997a). Biotechnology - Five Year Assessment. Report EUR 17591.

Commission of the European Communities (CEC) (1997b). Co-operation with third countries and international organizations - Five Year Assessment. Report EUR 17597.

Commission of the European Communities (CEC) (1997c). Biomedicine and Health - Five Year Assessment. Report EUR17592.

Dalton, D. H. and Serapio, M.G. (Jr) (1995). Globalizing industrial research and development. US Department of Commerce, Office of Technology Policy- Asia-Pacific Technology Program, pp. 182.

DaSilva, E. J. and Taylor, M. (1998). Island communities and biotechnology. EJB: Electronic Journal of Biotechnology. 15 April 1998, vol.1, n.1. Available on the Web: http://ejb.ucv.cl/content/vol1/issue1/full/1/index.html. ISSN 0717-3458.

Daza, C. (1998). Scientific research and training in biotechnology in Latin America and the Caribbean: The UNU/BIOLAC experience. EJB: Electronic Journal of Biotechnology. 15 August 1998, vol.1, n.2. Available on the Web: http://ejb.ucv.cl/content/vol1/issue2/full/5/index.html. ISSN 0717-3458.

Deleuze, G. (1988). Foucault. Athlone Press, Edinburgh, pp. 154.

Department of Trade and Industry (DTI) (1999). Bioguide, Stationery Office, London, pp 82.

Directorate Generale XII (DG XII) (1998). Annual Report of EU R & D Activities. Office of Official Publications of the European Communities, Luxembourg.

Directorate Generale XIII (DG XIII) (1997). Report of the Biotechnology. Entrepreneurship Workshop. Amsterdam, 27th June 1997.

Dorebjee, S., Lumley, C. E. and Cartwright, S. (1998). Culture, innovation and successful of new medicines - an exploratory study of the pharmaceutical industry. Leadership and Organization Development Journal 19:199-210.

*DR Report (1996). Outlook for Biopharmaceutical technologies to 2005. San Francisco, USA.*

DR Report (1997). The Biopharmaceutical industry in transition: Prospects for growth. San Francisco, USA.

Dunning, H. (1997). Alliance capitalism and global business. Routledge, London, pp 82.

Dunning, J. and Cantwell, J. A. (1991). Multinational enterprises technology and the competitiveness of European industries. In: European Economic Integration. G. R. Faulhaber and G. Tamburini (eds.), pp. 117-148. Kluwer, Netherlands.

Elliot, R. (1996). Discourse analysis: Exploring action, function and conflict in social texts. Marketing Intelligence and Planning 14:65-68.

European Federation of Biotechnology (EFB) (1999). Biotechnology Legislation in Central and Eastern Europe. Briefing paper Nº9. Available on the Web: http://www.kluyver.stm.tudelft.nl/efb/TGPPB/eng9.htm.

European Federation of Biotechnology (EFB) (1998). Dialogue in Biotechnology, Report on the workshop held at the Palais des Congres Brussels, 20th April 1998. Available on the Web: http://efbweb.org/efb1.htm

*European Federation of Biotechnology (EFB) (1997). Dialogue in Biotechnology, Briefing Paper Nº7. Available on the Web:* http://www.kluyver.stm.tudelft.nl/efb/TGPPB/eng7.htm

*European Federation of Biotechnology (EFB) (1996). Patenting in Biotechnology. Briefing Paper Nº1. Available on the Web:* http://www.kluyver.stm.tudelft.nl/efb/TGPPB/eng1.htm

European Federation of Biotechnology (EFB) and European Molecular Biology Organization (EMBO) (1999). Focus on future issues in biotechnology. Workshop report, Killiney Bay, Dublin.

Federal Co-ordinating Council for Science, Engineering and Technology (FCCSET) (1992). Biotechnology for the 21st Century: Realizing the promise. Available on the Web: http://www.nal.usda.gov/bic/Federal_Biotech/biotech94.fccset.html.

Foss, N. J. and Knudsen, C. (1996). Towards a competence theory of the firm. Routledge, London, pp. 216.

Galhardi, R. M. A. A. (1994). Small high technology firms in developing countries: The case of biotechnology. Aldershot, Averbury Press, pp. 234.

Ghijsen, H. (1999). Plant variety protection in a developing and demanding world. Biotechnology and Development Monitor 36:2-5.

Hayward, S. (1998). Towards a political economy of biotechnology development: A sectoral analysis of Europe. New Political Economy 3:79-101.

Holland, J. (1999, March 16). DuPont to pay $7.7 billion for agribusiness giant. San Diego Union Tribune, pp. C-2.

Holland, S. (1993). The European imperative: Economic and social cohesion in the 1990's. Spokesman Press, London, pp. 266.

International Monetary Fund (IMF) (1997). International Financial Statistics, 834 pp.

International Prospective Technology Studies (IPTS) (1997). A prospective analysis of European pharmaceutical research development and innovation. Working Report.

Joint Economic Committee (of the US Senate) (1999). Putting a human face on biotechnology. Available on the Web: http://www.senate.gov/~jec/bio_report.htm.

Kawamura, K. (1998). International Harmonization of regulation in Japan – what does the future hold? Pharmaceutical Technology Europe 10:38-47.

Kogut, B. and Zander, L. (1993). Knowledge of the firm and the evolutionary theory of the multinational corporation. Journal of International Business Studies. Fourth Quarter, pp 625-645.

Kupper, T. (1999, January 10). Bioprospecting goes to the ends of the earth in search of wonder drugs. San Diego Union Tribune, pp. I-1.

Kyriakou, D. and Gilson, D. (1998). Biotechnology and healthcare: Consumer related aspects. International Prospective Technology and Studies Report 30:20-26.

LaFee, S. (1999, march 24). Smart money. In: Science today, the question is: Who will own your next great idea? San Diego Union Tribune, pp E-1.

Lawton, T. (1997). Technology and the new diplomacy. Aldershot, Avebury, pp. 296.

Mason, M. (1994). Elements of consensus: Europe's response to the Japanese automotive challenge. Journal of Common Market Studies 32:435-453.

Metcalfe, J.S. (1998). Science policy and technology policy in a competitive economy. International Journal of Entrepreneurial Behaviour and Research 1:9-43.

Ministry of International Trade and Industry (MITI) (1998). Annual Report on the Promotion of Science and Technology 1998 (Summary). Available on the Web: http://www.sta.go.jp/policy/seisaku/nenjiho96/index.html.

Mitchell, G. R. (1997a). Korea's strategy for leadership in research and development. US Department of Commerce, Office of Technology Policy.

Mitchell, G. R. (1997b). The global context for US technology policy. US Department of Commerce, Office of Technology Policy.

Morgan, D. (1999, March 4). Monsanto's stock rises on talk of merger with DuPont. San Diego Union Tribune, pp. C-2.

National Institute of Sciences and Technology Policy (NISTEP) (1997). Science and technology indicators: 1997. NISTEP Agency, Report Nº50. Available on the Web: http://www.nistep.go.jp/achiev/report50-e/loc.htm.

National Science and Technology Council (NSTC) (1999). Bioinformatics in the 21st Century. Available on the Web: http://www1.whitehouse.gov/WH/EOP/OSTP/NSTC/html/nstc_pubs.html.

National Science Foundation (NSF) (1998a). NSF/Tokyo Report - Supplemental budget request of the Science and Technology Agency. Available on the Web: http://www.nsf.gov/pubs/1998/int9820/trm9811.doc.

National Science Foundation (NSF) (1998b). Japan's science and technology policy: Retooling for the future. Available on the Web: http://www.nsf.gov/pubs/1998/int9812/int9812.txt.

National Science Foundation (NSF) (1995). Implications for the United States. NSF 95-309. Available on the Web: http://www.nsf.gov/sbe/srs/s4495/implicat.htm

*National Science Resource (1996). Science and engineering indicators, pp.154.*

*Nature Biotechnology (1998). Bioentrepreneurship I. Supplement, May*

*Nature Biotechnology (1999). Bioentrepreneurship II. Supplement, February*

Newsedge (1999a, April 19). UK Government: Sainsbury announces biotechnology clusters team, pp. 2-3.

Newsedge (1999b, April 21). Europe biotech sector sees growth despite UK pain, pp.1.

Newsedge (1999c, April 22). British Biotechnology firm increases losses but cites breakthroughs, pp. 3-4.

Nijar, G. S. (1999). Community intellectual rights protect indigenous knowledge. Biotechnology and Development Monitor 36:11-12.

Nonaka, I. (1996). The knowledge creating company. In: How Organizations learn. K. Starkey (ed.), pp. 18-32. Thomson Business Press, London, UK.

Office of Technology Policy (OTP) (1997). International plans, policies and investments in Sciences and Technology. USA Department off commerce, 34 pp.

*Organization for Economic Co-operation and Development (OECD) (1996). Korea: OECD Economic Surveys: 1996. Paris, France.*

Owain, I. (1998). Working paper on TRIPs presented at the 1998 IPEG Workshop session, Liverpool, October.

Patel, P. (1997). Localised production of technology for global markets. In: Technology, globalization and economic performance. D. Archibugi and J. Michie (eds.), pp. 198-214. Cambridge University Press.

Peterson, J. (1994). High technology and the competition state: An analysis of the eureka initiative. Routledge, London, pp.287.

Powell, C. and Pearson, A. (1995). The development and survival of SMEs in the pharmaceutical industry. 3rd High Technology Small Firms Conference, Manchester Business School. 18th-19th September.

Ring, P. S., Lenway, S. A. and Govekar, M. (1990). Management of the political imperative in international business. Strategic Management Journal 11:41-151.

Science and Technology Agency (STA) (1998). Globalization and the Japanese economy. Available on the Web: http://www.sta.go.jp/policy.

Science and Technology Agency (STA) (1997). Surveys of R & D in 1996/1997. Available on the Web: http://www.sta.go.jp/policy/e-seisaku.html.

Seiler, A. (1998). *Sui Generis* systems: Obligations and options for developing countries. Biotechnology and Development Monitor 34:2-5.

Sklair, L. (1998). Globalization and the corporations: The case of the California Fortune Global 500'. International Journal of Urban and Regional Research 22:195-215.

Slater, A. E. (1998). The importance of the pharmaceutical industry to the UK economy. Journal of Management in Medicine 12:5-20.

Slater, A. E. (1996). 'Can we afford to lose the pharmaceutical industry in the EU? European Business Review 96:18-25.

Solleiro, J. L. and Castañon, R. (1999). Technological strategies of successful Latin American biotechnological firms. EJB: Electronic Journal of Biotechnology. 15 April 1999, vol.2, nº1. Available on the Web: http://ejb.ucv.cl/content/vol2/issue1/full/4/index.html. ISSN 0717-3458.

Spender, J.C. (1996). Making knowledge the basis of a dynamic theory of the firm. Strategic Management Journal 17:45-62.

Stopford, S., Strange S. and Henley, J. (1991). Rival States, rival firms. Cambridge Studies in International Relations, Nº19. Cambridge, Cambridge University Press.

*Strange, S. (1988). States and Markets. Routledge, London, pp. 272.*

Thumm, N. (1999). Patent protection for biotechnological inventions: Incentive for European Biotech innovators. International Prospective Technology Studies Report 33:27-34.

*Trott, P. (1998). Innovation and new product development. Financial Times – Pitman, pp.303.*

Verastegui J. (1999). Transferring expertise and building capacities in agribiotechnology: The experience of CamBioTec. Biotechnology and Development Monitor 39:2-3.

Wechsler, J. (1998). Washington Report – Pressures and Priorities. Pharmaceutical Technology Europe 10:18-27.

Welles, E.O. (1999). The Awakening. Available on the Web: http://www.inc.com/incmagazine/archives/01950231.html.

Werner, R. G. (1998). The value of contract manufacturing. Pharmaceutical Technology Europe 10:60-71.

Wolf, O. (1999). Transatlantic investments and human capital formation: The case of biotech firms'. International Prospective Technology Studies Report 33:34-39.

Wyatt-Walter, A. (1995). Globalization, corporate identity and technology policy. Journal of European Public Policy 2:12-24.

Zucker, L.G. and Darby M.R. (1998). Capturing technological opportunities via Japan's star scientists: Evidence from Japanese Firms' biotechnology patents and products. Available on the Web: www/papers.nber.org/papers/w6360.