COMPETITIVENESS IN THE PHARMACEUTICAL INDUSTRY: A COMPARATIVE ANALYSIS

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The study analyses global trends in the development of pharmaceutical and biotechnology sector. Focusing on the issue of competitiveness, this study examines (a) the indicators derived from patent data, and (b) their 'contribution to the trade balance' index (CTB index). In analysing the determinants of competitiveness, the study concentrates on two critical elements: (a) the role of the growing convergence of information and biotechnologies, and (b) the role of venture finance in the commercialisation of research. A review of selected studies indicates that venture capital mechanism differs significantly among OECD countries in several respects, particularly in areas like sources of venture funds, organisational structure of venture finance, and financial contracting systems including exit mechanism.

I- Introduction

Pharmaceutical industry is a high technology and science-based industry, performing above-average levels of R&D. Technological innovations in life sciences are originating and are fed from advances in multidisciplinary fields like biotechnology, genomics, computing, and communication technologies. Biotechnology is a set of emerging technologies that are not only creating entirely new types of products and services, but also biotech processes and products that are applied in all types of manufacturing, agriculture, aquaculture, and even at the microbial and nano-scales. Applications of biotechnology are found to be more predominant in the fields of medicine and medical devices. Approximately one-fifth of the new molecular entities launched on the world market each year are now derived from biotechnology.

The pharmaceutical industry is highly globalised, with many pharmaceutical companies operating in multiple countries. Adding to the international nature of the industry, there is a continued trend towards outsourcing various stages of the development and production of a single pharmaceutical product. There is now a growing recognition that industrial R&D performed by high technology industries benefits other

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commercial sectors by generating new products and processes that increase productivity, expand business, and create high-wage jobs.† Globally networked regional clusters are growing in biotechnology. In the context of the biotechnology industry, Coombs and Deeds (2000) find statistical evidence that foreign firms actively develop relationships with biotechnology firms embedded in geographic locations having a support structure for the biotechnology industry. Dalton et al(1999), in their study, note that industrial R&D has become increasingly globalised, with significantly more foreign R&D in the United States and the R&D of US abroad.

II- A Brief Review of the Approach and Plan of the Study

This study analyses global competitiveness of major producers in the pharmaceutical industry. Academic researches on competitiveness emphasise innovations as one of the key sources of competitiveness in the pharmaceutical industry[(Gambardella et al(2000)]. Measurement of the country's innovative potential is a difficult task and is beset with problems. Existing studies have used different indicators like R&D intensity, New Chemical Entity (NCE) discovery, and patents per million spent on R&D. However, none of these indicators can conclusively shed light on the relative competitiveness of countries in the pharmaceutical industry, partly because each one refers to different stages of the R&D process and cannot provide a comprehensive analysis of the overall performance of a company or the industry. For instance, a high R&D spending is a necessary but not a sufficient condition to the development of innovative drugs. By contrast, a considerable amount of R&D may be devoted to imitation and duplication of research performed by others. Similarly, a high number of patents does not imply a commercial success of the products involved. Nevertheless, a combination of these indicators could provide some guidelines for the future direction of the industry as a whole or of individual companies. The current study uses two measures of global competitiveness: (a) country's share in patents related indicators and (b) industry's contribution to the country's trade balance (CTB). The next section analyses global competitiveness in terms of the above-mentioned measures.

In section- III, the study discusses the determinants of competitiveness. It is widely accepted that self-sustaining innovation is an ongoing and

† See OECD (2004): Science Engineering Indicators (2004), Chapter-6, Industry, Technology, and Global Market Place.

iterative, and involves many actors drawn from a variety of economic sectors, scientific and technological disciplines, and regions. In this complex process, markets often stimulate development of new technologies, and product or process development stimulates scientific and technical research.[‡] Etzkowitz (2002b), in his 'triple helix model'[§] of innovation, describes knowledge-based economic development as a three-stage process: (a) creation of 'knowledge spaces', (b) creation of a 'consensus space'[**] and (c) 'innovation space' (the venture capital firm provides business advice, technical assistance, and financing to start new firms). The American model of knowledge commercialisation is based on connecting the patent system to the intellectual output of the university research group, on the one hand; and integrating the research group into an organisational network of transfer offices, incubator facilities, and venture capital firms, on the other (Etzkowitz .2002a). Many countries are emulating this model, but without much success. Studies indicate that firms in several OECD countries lag behind the United States in their ability to commercialise national biotechnology research efforts. Commenting on the relative weakness in the commercialisation of science from the research base across Europe, Cook (2000) emphasises the following three key elements: exploitation of basic science, venture capital, and cluster-formation. Given the importance of venture finance in 'bridging knowledge to commercialisation' as illustrated in the above researches, the present study concentrates on the role of venture capital finance in section 3.2[††].

In addition, the growing convergence (or synergy) of information

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[‡]Based on US experience, Etzkowitz (2000a) elaborates this complex process by combining what he calls 'assisted linear model of innovation' (which has two elements: (a) search mechanism, the technology transfer and licensing office and (b) the venture capital firm) and 'Triple Helix ' model. See also the concept of reverse linearity in the context of multi-faceted role of industry.

[§] The "triple Helix' is a spiral model of innovation that captures multiple reciprocal relationships at different points in the process of knowledge capitalization. The triple Helix denotes the university-relationship. See details in Etzkowitz (2002b).

[**] It is a venue that brings together persons from different organizational backgrounds and perspectives for the purpose of generating new strategies and ideas. In knowledge space, the focus is on the 'regional innovation environment' and resources. In Consensus space, ideas and strategies are generated in a triple helix of multiple reciprocal relationships among institutional sectors (academic, public, industry).

[††] The detailed discussion on commercialisation and innovativeness is available in Bhardwaj (2005).

technology (IT) and biotechnology [see Ernst and Young(2001)][‡‡] is significantly enhancing innovative capabilities of pharmaceutical companies. The advances in IT and the consequent growth in B2B's technologies and platforms are posing new challenges. The growth of e-commerce marketplace for the health services is changing the competitive game in the global business of pharmaceutical and biotech sectors. This study describes competitiveness in Section- III, reviews the role of IT in Section- IV, and presents conclusion in Section- V.

III- Competitiveness

Competitiveness is examined on the basis of (a) the indicators derived from patent data, and (b) the 'contribution to the trade balance index '(CTB index). As new products are the engines of growth in this industry, companies rely on strong intellectual property rights to protect their research investment and sustained earning flows from royalties and fees. Due to the lack of comparable data for countries in this area, this study does not go into this area.

III- 1: Evidence from Triadent patent families

One recent study of OECD [Lichtenberg and Virabhak(2002)] reports "Triadic Patent Families", which are sets of patents covering a single invention, filed altogether in Europe, Japan, and the US.[§§] This study reports that there were nearly 40 000 health-related patent families filed in the 1988-1995 period, which is 16% of the total number of patent families, with a majority (58%) of Medical Preparations (mainly drugs), followed by Surgery (13%), Media Devices (10%), and Prostheses (9%). The share of health patent inventors residing in the US is 56% (it is 35% in all families), EU is 27% (32% in all families), and Japan is 11% (28% in all families). Looking at countries individually, Japan comes a distant second to the US, with over 10% of the inventors. Germany (7.54%),

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[‡‡] The convergence of biology with computing and nanotechnology is expected to yield tremendous opportunities to create new, safer, and more effective medicines. Nanotechnology embraces several disciplines operating on a very small scale, at mainly molecular and atomic levels. Some of its applications impinge on the medical sciences and open new possibilities for pharmaceutical R&D and thus for the prevention and treatment of disease.

[§§] "Triadic Patent Families" database consolidates raw patent data from the EPO (and the WIPO DOCDB database it maintains), JPO, and the USPTO. http://www.olis.oecd.org/olis/2002doc.nsf/43bb6130e5e86e5fc12569fa005d004c/db7182d5e0c8f2efc1256cb0005b00ce/$FILE/JT00137753.DOC.

France (5.72%), and the UK (5.54%) following closely behind. An analysis into three distinct periods – 1988-1989, 1990-1992, and 1993-1995 shows that the US has been the top contributor to new health technology over these years. It is found that the share of the US has been increasing between 1988 and 1995. The US is showing a clear comparative advantage in health-related technology, as its dominance is strongest in this area. Other countries showing an increasing and a higher share of health patents compared to the country's overall share in patent families include Canada, Denmark, Ireland, and Sweden. This indicates the persistence of innovativeness in the USA.

Exploring the link between R&D and patents, studies have shown that there is a strong relationship between R&D efforts and patents [see details in Lichtenberg and Virabhak(2002)]. Using patent data and the data on R&D expenditure, Lichtenberg and Virabhak(2002) estimate an econometric model and show that R&D has a significant and positive impact on patents, with an R&D elasticity equal to 0.43. Accumulated knowledge, captured by the patent stock variable, is also an important determinant (elasticity of 0.79).

The above OECD study also finds that internationalisation of research (measured by the share of patents with inventors residing in two or more different countries) grew steadily between 1988 and 1995. Research is much more internationalised in drugs than in other health fields.

III- 2: Scientific publications in biotechnology and microbiology

Pharmaceutical firms are increasingly becoming dependent on the biotechnology industry for the key innovations that are necessary to compete effectively in the marketplace against cheaper generic alternatives. The pharmaceutical industry's response has been to focus on delivering better products through biotechnology. Currently, more than two-thirds of the roughly 3,000 drug compounds under development are being engineered in biotech labs. One measure of scientific output in a field such as biotechnology or applied microbiology is the share of publications in scientific journals. Table-1 (Biotechnology and Bibliometrics) shows that the United States and Japan together account for about one third of all publications in these fields. Scientific publications are considered as a key channel to international access of knowledge.

Table-1: BIOTECHNOLOGY AND BIBLIOMETRICS-National Shares of the total number of Publications in the Biotechnology and Applied Microbiology NSIOD Journal Category

Countries	1986	1997	1998	Mean
Belgium	1.0	1.4	1.0	1.2
Canada	9.4	5.1	3.8	8.2
Denmark	0.6	1.1	1.4	0.8
Finland	1.1	0.8	0.7	0.9
France	7.4	7.5	7.3	5.9
Germany	5.4	6.3	6.9	6.0
Italy	1.1	2.7	2.6	2.1
Japan	10.9	11.6	12.9	12.1
Netherlands	2.2	3.1	3.0	2.4
Norway	0.1	0.4	0.5	0.2
Spain	1.8	4.5	4.8	2.6
Sweden	2.0	2.0	1.9	1.8
Switzerland	1.9	1.8	1.8	1.5
United Kingdom	12.4	8.6	8.7	9.3
United States	22.9	21.8	21.0	23.9
Other countries	19.8	21.3	21.7	20.3
	100.0	100.0	100.0	
Total number of papers	1 574	3 265	3 261	34 489

Source: OECD, based on data from NUTEK Sweden.

Data for patents in biotechnology indicates that, in 1999, the United States accounted for just under half of all OECD biotechnology patent applications to the EPO; whereas, Germany and Japan accounted for about 10% each. In terms of biotechnology patents, Denmark and Canada are highly specialised with a specialisation index of 2.2. The following table, which is prepared from OECD Patent database, reports data for selected countries.

Table- 2: Average EPO Biotechnology Patent Applications Specialization Index# for Priority Years: 1995-1999

Countries	1995-99	OECD=1
Denmark	2.24	1
Canada	2.15	1
Australia	2.00	1

New Zealand	1.79	1
Mexico	1.77	1
United States	1.70	1
Belgium	1.51	1
United Kingdom	1.36	1
Ireland	1.26	1
Netherlands	0.96	1
France	0.67	1
Austria	0.60	1
Switzerland	0.60	1
Japan	0.59	1
Sweden	0.52	1
Germany	0.48	1
EU	**0.69**	**1**

Source: OECD, Patent database, May 2003.

The specialisation index indicates a country's share of biotechnology patents divided by its share in total patents.

It is observed from Table-2 that the European Union with an index of 0.7 is less specialised in biotechnology than North America.

III- 3: Industry's contribution to country's trade balance

As the number of pharmaceutical and/or biotechnology patents is a relatively crude measure of the industry's performance, additional indicators need to be considered, including the industry's contribution to country's trade balance. This indicator is considered more appropriate than other measures used in empirical analysis to measure "revealed comparative advantage". It is calculated as the difference between the actual net balance and the theoretical net balance. The theoretical net balance corresponds to the net value that the sector (or market) under analysis would register when global equilibrium occurs in the country's trade. It takes into account not only exports, but also imports, and tries to eliminate business cycle variations by comparing industry's balance with the overall trade balance. A positive value for an industry indicates a structural surplus and a negative one a structural deficit[(see OECD Science, Technology, and Industry Scoreboard(2003)]. The following table, which shows the contribution to trade balance(CTB), reports the competitiveness measured in terms of this indicator for selected OECD countries.

Table-3: Contribution to Trade Balance (CTB) expressed in Hundreds of Manufacturing Trade

Countries	Pharmaceuticals		Medical Precision and Optical Instruments	
	1992	2001	1992	2001
Canada	-0.5	-0.8	-1.1	-1.2
Mexico	-0.2	-0.2	-0.3	0.3
United States	0.3	0.2	1.0	1.5
Australia	-0.6	-0.6	-1.3	-0.6
Japan	-0.6	-0.7	0.4	0.2
New Zealand	-1.4	-1.2	-1.3	-1.2
Austria	-0.2	-0.3	-0.4	-0.4
Denmark	1.0	2.4	0.6	0.9
Finland	-1.0	-1.1	-0.7	-0.3
France	0.3	0.4	-0.3	-0.3
Germany	0.3	0.4	0.4	0.3
Ireland	2.2	3.1	0.7	0.4
Italy	-0.5	-0.3	-0.8	-0.6
Netherlands	-0.1	-0.3	-0.2	0.0
Norway	0.0	-0.2	-0.7	-0.2
Sweden	1.0	1.6	-0.2	-0.3
Switzerland	3.5	3.8	4.9	4.8
United Kingdom	0.8	0.9	0.4	0.3
European Union	0.2	0.3	-0.1	-0.1
Total OECD	0.1	0.2	0.2	0.3

Note:- Observed trade balance of industry minus theoretical trade balance, expressed in hundreds of manufacturing trade *Source:* OECD, STAN database, May 2003.

Table-3 indicates US comparative advantage in biosciences. The other countries enjoying similar status, in our sample, include Denmark, Germany, Ireland, Switzerland, and UK. The US is a net exporter of biotechnology products, and, in 1999, the share of biotechnology in the technology trade surplus was twice as large as its share in technology trade. In other words, US exports of biotechnology products exceeded imports to a greater degree than was the case for technology products overall. These durable trade surplus points to a US trade specialisation

and suggests that the United States has a leading position on the international biotechnology market [(See details in Science, Technology, and Industry Scoreboard (2003)]. Similar conclusions are reported in the European Community Report (2002), which compares biotechnology with four other branches of the chemical industry: materials, organic chemistry, pharmaceuticals, and polymers. On the basis of Revealed Technological Advantage Index, the sectoral break down of patents by sub-sectors in the above study indicates that the US is comparatively more specialised in biotechnology innovations, and that some of the smaller European countries, notably the Netherlands, Sweden, Denmark, etc., show a greater specialisation in biotechnology than larger European countries such as Germany, Italy, and France.

IV- Determinants of Innovativeness

Systems of innovation can be national, regional, or sectoral [See Malerba(2003) for a discussion on the three levels of innovation model]. They coexist and complement each other. The interdependence between the national, regional, and sectoral systems of innovation for biotechnology is recognised by several authors because of its knowledge-intensive and research-led nature [See, Senker and Zwangenberg(2001), Gambardella *et al*(2000), and Owen-Smith *et al*(2002)]. Recently, OECD has initiated sectoral case studies of innovation in pharmaceutical and biotechnology industry. It is held that innovation greatly differs across sectors in terms of characteristics, sources, actors involved, the boundaries of the process, and the organisation of innovative activities[See Malerba(2003)]. In a similar vein, Kern and Enzing(2003) point out that innovative capabilities and performance of a nation are not only influenced by nationally determined factors, but also by the idiosyncratic characteristics of specific economic sectors and technological fields. A substantial body of literature also suggests that, in a world where R&D is mobile internationally, competitive innovation advantage is generated at the regional rather than at the national level[Cooke(2002), Cantwell and Iammarino(2000), and Harding (1999)]. Spatial proximity is considered to be instrumental in facilitating knowledge flows among the actors of a system of innovations. According to some authors, regions are important as the point of delivery but that the sources of learning and added value actually rest in the networks that individual researchers have nationally and internationally.[***] It is important to stress here that a triple helix of

[***] For more discussion on these issues, see Bhardwaj (2005).among others.

overlapping spheres of university-industry-government is increasingly the core, rather than periphery, of national, regional and multi-national innovation systems [See Etzkowitz(2003)]. With its focus on knowledge commercialisation aspect of innovation, the present study discuses the role of venture finance in the firm-formation process (see section 3.1). Public and private venture capital contributes to the creation of an innovation space [Etzkowitz(2002b)] is one of the three-stage process of knowledge-based economic development.

The subsection below highlights the role of the growing convergence or synergy of information technology (IT) and biotechnology. This is then followed by a discussion on the role of the venture finance in subsection 4.2.

IV- 1: The role of the convergence of information technology and biotechnology

The growing convergence of IT and biotechnology is changing every aspect of health care, from preventive medicine to the most invasive surgical therapies, and hospital care. Information technologies are influencing the developments in pharmaceutical companies in two significant ways: (a) through speeding the drug development process, achieving productivity gains, including therapeutic agents, and (b) through facilitating international trade in health services via B2B exchanges.

IV-1-1: IT and productivity gains within the biotech and pharmaceutical sectors

IT developments are quickening the pace of biotechnology research. It is widely recognised that high-speed computers have facilitated the advances in biotechnology by performing tasks such as mapping the human genome. Biotechnologists, chemists, and pharmacologists employed to synthesise drugs and therapeutic agents in a more rational way are exploiting advances in data management technology. This structure-based drug design (rational drug design) presents a great potential in developing novel therapeutic agents. Small biotech firms can discover new drugs as fast as large drug companies. In discovering the next generation of medicinal products, new technologies are being integrated with different disciplines. For example, information technology is used and applied in the computational chemistry and the integration of biology for the understanding of disease mechanisms and semiconductors for the development of a bio-chip used in a high

throughput screening. Current pharmaceuticals and biologics focus on about 500 molecular targets. Advances in genetics may yield as many as 10,000 more. The data mining capabilities and advanced simulation computer programs/models are helping researchers to study the potential efficacy of various medications, and conduct "virtual" drug testing[see Ernst & Young(2001, p11)]. In comparison with traditional perceptions of the purposes and nature of research and development in pharmaceuticals,[†††] the future medical management paradigm is likely to include the "diagnosis and treatment of illness" pattern, which is the "accurate prediction and prevention of disease". Research on development of new intervention agents will concentrate precisely on targeted molecules, which are economically structured to achieve specific purposes with minimum adverse/side effects.

IV-1-2: Information technologies, B2B exchanges, and cross-boarder trade of health services, including telemedicine

Recent advances in information and communications technology have made cross border supply of health services possible. The pharmaceutical industry supply chain is expected to experience the largest increase in B2B exchanges [See Ernst and Young(2001)]. According to GATS, health services are internationally traded and delivered through one or more of the following modes: Mode 1:Cross-border services (the service itself crosses the border, the example- telemedicine, telepathology, teleradiology, and telepsychiatry); Mode 2: Consumption abroad (example- a patient travels abroad for diagnosis and treatment); Mode 3: Local presence (services are supplied through a facility in another country), and Mode 4: Movement of persons (example: doctors and other personnel travel abroad to provide their services[(see details in Chanda(2001)]. In 2000, the Centre for International Business Studies in Alberta, Canada, estimated the global demand for telehealth services to be worth approximately US$1.25 trillion.

By removing cost barriers and transcending geographical boundaries, IT is acting as a key enabler of globalisation, integrating organisations and processes into a single marketplace. Business to business exchanges (B2B) and telemedicine are two leading examples of how IT is transforming the health services market[Ernst and Young(2001)]. The development of B2B exchanges is markedly changing the competitive

[†††] In the past, the emphasis was on drugs for curing or alleviating disease or on minimizing the risks of acquiring natural infections with crude vaccines that would provoke humeral antibodies.

strategies of pharmaceutical companies in their globalisation business. The following are, among other, major trends that are becoming prominent [Ernst and Young (2001)] in recent years :(a) several large pharmaceutical companies have formed B2B consortium to exchange clinical contents, and buy, sell, and distribute medical services, products and equipment on global basis; (b) several independent B2B exchanges are directly connecting pharmaceutical and biotech manufacturers to retail and hospital clients, thus reducing costs of transactions for all participants.

Global telecommunications networks could, thus, contribute significantly towards the achievement of a healthier world. However, in order to promote and facilitate the implementation of telemedicine and telehealth networks around the world, there is a number of challenges to resolve. The Internet's vulnerabilities pose enhanced and unique concerns relative to informational health, privacy, and pharmacy sales [Rothstein(2001)]. Rothstein's (2001) study relating to US and Canada indicates that both countries face difficult decisions as to how to facilitate and encourage growth in this valuable medium; while, at the same time guarding against fraudulent activity. While both countries have enacted federal laws that overlay state- province, and territory-specific licensure laws, the above study stresses that there is a need for a national or mutual recognition approach to local licensure[‡‡‡]. An additional problem, at the global level, is that different countries have different health care policies. Here is a need for promoting international collaboration in telemedicine and health telematics.

From a global perspective, a group of national representatives of the G-8 Global Healthcare Applications Project (GHAP) sub-project four (SP-4) developed a set of recommendations during a series of forums and workshops held between 1997 and 1999. Lacroix, et al.,(2002) published these findings recently [Laxminarayan and Stamm (2002)[§§§]] with the main emphasis on five categories; namely, standards and network stability, organisational issues, human factors, evaluation of services, and the medico-legal aspects. Many of the problematic issues include interoperability, security, issues of licensures, bandwidth on demand, development of multilingual systems, economical viability,

[‡‡‡] This is because pharmacies in both Canada and the United States must seek local licenses from each state/province/territory in which they wish to sell prescription medications.

[§§§] See Laxminarayan and Stamm (2002).

reimbursements, the referral patterns, and the various ethical and medico-legal guidelines. One of the great challenges facing telemedicine and telehealth is the global digital divide. The available technological infrastructure along with cultural and economic structures of different countries, makes dissemination of technology variable. One of the important obstacles is the dilemma of cross-national regulation of healthcare.

IV-2: Venture capital funding and commercialisation of research

In high tech industries, "first mover advantage" may be created by special intuitional developments and business environment. According to the Brookings Institution Report [Cortright and Mayer(2002)], "first mover" advantages are realised by establishing either (a) an early lead in the technology or (b) a build-up on the basis of local pharmaceutical industry leadership, or (c) exceptionally entrepreneurial culture/spirit or some other special conditions. The availability of capital plays an important role at every stage of the process of moving an idea along the path from technology transfer to technology commercialisation.**** Venture funds are key players underlying a country's entrepreneurial performance. The venture firm in USA provides both funding and business assistance. The latter function has, to some extent, devolved into the incubator faculty, an intermediary organisation between the transfer office and the venture firm [Etzkowitz (2002a, P1)].

In the past few years, there has been a radical change in the nature of drug development brought about by discovery and implementation of

**** There are three sources of capital flow: venture capital, research alliances, and initial public offering. The US experience indicates that start-up firms typically depend on venture capital investment to underwrite their initial costs. Small biotech firms with more ideas than money will form research alliances with larger pharmaceutical firms, trading equity or future marketing rights for up-front cash. Once some promising products are developed, venture capitalists and other early-stage investors seek to recoup their investment (or a portion of it) by having the firm issue stock to the public in an "initial public offering" (See Cortright and Mayer, 2002). Pre-venture financing for the creation of new biotech knowledge comes substantially government sources. See also Texas Report to Governor (March 2003), which explains capital stages of Biotechnology Commercialization (based on Jolly. V. 1997: Commercialising New Technologies. Harvard Business School Press). The important stage in most studies is the pre-clinical trial and applied research phase. Angel capital and incubators support becomes a critical factor for advancing to clinical trials, which again depends on different sources of funding.

recombinant DNA technology and genetic engineering. Developing new therapeutic innovations, now, requires firms to follow highly uncertain and risky knowledge trajectories that make it difficult for firms to predict and develop future skill and knowledge needs internally. A major part of the work is conducted in small entrepreneurial biotechnology companies that are characterised by a high innovative and technological change[Whittle(2002)]. Innovations in biosciences, thus, are coming from the transfer of discoveries in basic research at universities to the private sector through the creation of new companies. The critical factor in the commercialisation activity is not only the availability of pre-commercial medical research but also the availability of private sector investment in product development. These biotechnology firms, which often have a high R&D expenditure, face volatile industry environment and limited revenues for several years. Biotechnology has long been identified as a "radically innovative" industry due to the importance of university science in the success of companies.

The following table provides the flow of venture capital in selected countries over the period 1995-2001.

Table- 4: Biotechnology Venture Capital per million units of GDP from 1995-2001

Countries	1995	2001
Canada	92.0	443.1
United States	112.2	339.1
Belgium	47.6	256.7
Germany	8.3	240.2
Denmark	12.9	229.5
Australia	78.0	213.4
Sweden		135.4
New Zealand	35.6	70.6
Korea	21.9	56.8
Norway		54.7
United Kingdom	53.1	51.3
France	22.4	50.9
Finland	10.4	48.7
Netherlands	45.1	48.4
Iceland		36.4
Austria		28.6
Japan	3.1	9.6
Switzerland		8.0

Italy	2.1	4.9
Spain		0.5

Source: OECD, Venture capital database, April 2003.

It is seen from Table- 4 that Canada and the United States are the countries in which the largest shares of venture capital go to biotechnology.[††††]

But, cross-country comparisons warrant a careful interpretation of the figures, because data aggregation may yield misleading results by masking compositional differences, and also by overlooking different definitions underlying the reported data. Studies show that the chief differences between European and American venture capital lie [Bottazi and Rin (2001)] in (1) the development stage of the portfolio companies able to attract venture financing, (2) the principal sources of funds for venture capital investing, (3) the organisation of the venture funds themselves, (4) venture-backed IPOS (market capitalisation and exit mechanism), and (5) public policies. These aspects are reviewed below in order to understand the link between venture capital funds and entrepreneurial performance, particularly when undertaking cross-country comparisons.

IV-2-1: Venture capital investment by the stage of development

The aggregate data for funding comprise two very different types of data: they include funds raised by venture capital, but also funds raised by firms which specialise in management buy-outs (MBOs). This is because the European Venture Capital Association includes MBOs and MBIs (Management Buy-ins) in the definition of the venture capital [Bottazi and Rin(2001)]. Data for venture expenditure are comparable among countries, when only seed, start-up and early stage capital, and not replacement capital and buyout are included in the definition[Bottazi and Rin (2001)]. Once we compare the amount of funds raised with that of funds invested into venture capital proper, we see the performance of European is less thrilling than suggested by the aggregate data on investments [Bottazi and Rin (2001)]. A recent study by OECD Secretariat (2004) points out that, while the United States and Canada[‡‡‡‡] have effectively channeled funds to early-stage investments on the

[††††] About Canada, see Niosi (2003) for more details.

[‡‡‡‡] For Canada, there is a need for further comments (see below) about the suitability of certain venture funds for technology-based start-ups.

average around 0.15% of GDP between 1999-2002, early stage financing constituted a lower share of the total invested in other OECD countries such as the Netherlands and the United Kingdom, amounting to 0.06% of GDP'. Another factor that may explain the relative gap between the performance of the US and the European venture funds is that, while Europe invests much less in venture capital than the U.S., it supports a much larger number of companies, nearly twice as many. This means that the average amount invested per company is much smaller in Europe, where money is spread very thinly across companies [Bottazi and Rin (2001)].

IV-2-2: Principal sources of funds for venture capital investing

US firms benefit from a continuum of finance provided by pension funds, institutional investors, and corporations stimulated by liberal investing rules and fiscal incentives, active business angel networks, government funds, and well functioning second-tier stock markets [Baygan(2003b), OECD]. Institutional investors are by far the largest contributors in the US, accounting for nearly two thirds of all funds, as compared to less than one third in Europe [Bottazi and Rin (2001)]. European venture capital is instead dominated by funding from financial institutions. In general, institutional investors are more likely than either individuals or corporations to take a longer view, and continue venture inflows in depressed markets [Baygan (2003a), OECD]. In Canada, the institutional investors have not been active in Canadian venture capital markets, in spite of their large asset holdings. Labor Sponsored Venture Capital Funds (LSVCFs) accounted for about 17% of venture capital investments in 2001. Other domestic sources of Canadian venture capital in 2001 included private venture funds (13%), corporations (10%), government funds (7%) and institutional investors including pension funds (7%). The access to financing for SMEs was largely through loans and LSVCFs, neither of which were particularly suited to technology-based start-ups. The high share of LSVCFs relative to private venture capital funds tended to reduce the quality of deals and equity supplies to other than traditional industries and existing firms. In some provinces the proliferation of LSVCFs tended to crowd out private investment and limit the growth of private funds [Baygan (2003c), OECD].

IV-2-3: The organisation of the venture funds

Megginson (2001) observes that, for a mix of cultural and legal reasons, the organisational model structure of venture capital funds in Europe

differs from that in the US. According to Megginson, European venture capital funds are rarely if ever organised as a stand-alone limited partnership sponsored by specialist venture capital firms staffed by technically trained professionals, as the model in the United States. Instead, funds are generally organised as investment companies under various national laws, and their approach to dealing with portfolio companies is much more akin to the reactive style of US mutual fund managers than to the reactive style of American venture capitalist [Megginson(2001)]. Venture capital firms in Europe are more deal makers and less active monitors. They seem to be lagging behind in their capacity to screen projects and add value to innovative forms [Hege, Palomino and Schwienbacher (2003)]. About Canada, the study of Cumming and Macintosh (2003) provides evidence that LSVCF structure and governance are inefficient. The authors point out that LSVCFs have grossly under performed while simultaneously attracting more capital than other forms of private equity.

IV-2-4: Venture-backed IPOS, market capitalisation and exit mechanism

One important indicator of venture funds performance in a country is the existence of a well-functioning exit mechanism, particularly in the form of initial public offerings (IPOs) on second-tier stock exchanges. The active and liquid stock markets make IPOs affordable for companies, attractive for investors, and create an exit mechanism[§§§§] for venture capitalists. Table: A-1 in the appendix provides information of the IPO activities in various countries. For Europe, one notices that a higher venture capital intensity does not necessarily correspond to a higher number of stock market listings. Venture high risk capital is hard to sustain in countries without large capital markets willing to support high risks initial public offering. The fragmentation of the European stock exchanges with the resulting limited capitalisation, and liquidity of individual markets seem to be an important barrier to development of

[§§§§] There are three principal methods of exiting an investment: (i) through an IPO of shares to outside investors, (ii) by selling the portfolio company directly to another company (the merger, or M&A option), (iii) by selling the company back to the entrepreneur/founder (the redemption option). IPOS are by for the most profitable and prestigious option(see details in OECD Secretariat 2004). For greater details and technical discussion on exit vehicles, see Cumming, D. and J. Macintosh (2000). In their study, comparing US and Canada, they presented evidence to the view that IPOs are central to the venture capital process. IPOs are the most frequently selected means of exit for high quality firms.

venture capital [Baygan(2003a), OECD]. The US stock markets have also not been completely sheltered from speculative surges and volatility. In the U.S., it is reported that, though in 2000, venture backed IPOs accounted for more than 50% of the total IPOs, compared to 20% in 1998, but venture backed IPOs fell over 80% in 2001[OECD(2004)]. Consequent upon this crash, the heightened activity in mergers and acquisitions, however, helped venture capitalists seeking exits and immediate liquidity. In response to the concerns regarding volatility in the markets, the listing requirements on the New York Exchange and NASDAQ are currently being amended in line with the Sarbanes-Oxley Act of 2002, which introduces stricter standards and disclosure rules for publicly traded stocks and IPOs.

Cumming and Macintosh (2000)*****, in a comparative study between Canada and the U.S., provide an insight into the impact of different institutional and legal constraints, and suggest such constraints have distorted the efficient pattern of exits in Canada. The highest amount of exits in UK in recent years has mainly been in the form of trade sakes rather than through IPOs [Baygan (2003a), OECD].

IV-2-5: Public policies

European governments have taken an activist approach to the promotion and support of venture capital [Lerner(2000), Jeng and Wells(2000)], and Megginson (2001) recommends that government efforts to promote a robust entrepreneurial sector would probably be better focused on eliminating regulatory roadblocks, lowering taxes, and providing more favorable business climate than attempting directly to identify and fund "sunrise" industries.

Based on the above observations and on certain academic research findings, the following recommendations may be made:

(a) To implement investment regulatory reforms, tax policies for venture

***** The study emphasises the importance of ensuring that regulatory hurdles to accessing public markets are cost-effective and not unduly onerous. It also emphasises the inextricable link between primary and secondary markets. The price at which securities are sold in primary market transactions reflects the expected liquidity of those securities in the secondary market.

fundraising; for example, pension regulations, capital gains tax, and policies promoting technology innovation [Gompers and Lerner(1998)], and appropriate macroeconomic policies like interest rate policies[Romain and Pottelsberghe(2004)], etc.

(b) To remove labor market rigidities [Jeng and Wells (2000), and Romain and Pottelsberghe(2004)] by using supportive, but non-interventionist government policies to promote knowledge, research and development, entrepreneurship [Jeng and Wells(2000)], and to ease restrictions on the flow of private capital.

(c) To promote second tier IPO market with emphasis on transparency, accountability, listing requirements, appropriate disclosure details[Baygan (2003b), OECD, and Jeng and Wells (2000)].

(d) To create liquid markets, reduce manager-shareholder agency problem and risk by using convertible securities, and stage financing, and creating a successful exit mechanism through removing institutional and legal constraints[Jeng and Wells (2000), and Cumming and Macintosh(2000)], and deal syndication [Schwienbacher (2002)]. For details on financial contracting, refer to, among others, Kaplan and Stromberg (2001b), Megginson(2001), Hege, Palomino and Schwienbacher(2003), Cumming and Macintosh (2000), and Black and Gilson (1998).

V- Conclusion

The study analyses global trends in the development of pharmaceutical and biotechnology sector. Focusing on the issue of competitiveness, we first examine (a) the indicators derived from patent data and scientific publications, and (b) the 'contribution to the trade balance' index (CTB index). Then, in section 3, we analyse the determinants of competitiveness, concentrate on two critical elements: (a) the role of the growing convergence of information and biotechnologies, and (b) the role of venture finance in the commercialisation of research. Information technologies are influencing the developments in pharmaceutical companies in two significant ways: (a) through speeding the drug development process including therapeutic agents, and (b) through facilitating international trade in health services via B2B exchanges. The growing flow of cross-border services, which is termed as Mode-1. It means the service itself crosses the border. The examples are telemedicine, telepathology, teleradiology, and telepsychiatry in GATS

terminology. The crossing poses a new challenge, and calls for a need of promoting international collaboration in telemedicine and health telematics.

Several studies have noted that the United States is increasingly the dominant player in the pharmaceutical sector. According to the competitiveness report [Gambardella, Orsenigo, and Pammolli(2000)], North America has become the main locus of innovation in pharmaceuticals, to which European companies turn to get knowledge. Studies indicate that firms in Europe lag behind the United States in their ability to commercialise national biotechnology research efforts. Cooke (2000) emphasises the following three key elements: exploitation of basic science; venture capital; and cluster-formation. The present study has made an attempt to compare the performance of selected OECD countries in the development of venture capital finance and its unique role of bridging knowledge to commercialisation in the US economy. A review of selected studies indicates that venture capital mechanism differs significantly among OECD countries in several respects, more particularly in areas like sources of venture funds, organisational structure of venture finance, financial contracting systems including exit mechanism, etc. The success of the US economy in the pharmaceutical and biotechnology sector owes much to some specific institutions and attitudes that are typical of the American environment and much less developed in Europe and elsewhere. Based on certain academic research findings on venture finance, we have briefly presented relevant recommendations.

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Appendix

Table A-1: Second-Tier Stock Markets in OECD Countries

Country (stock market)	Year of creation	Number of initial public offers (IPOs)				Number of quoted companies				Market capitalization (% GDP)			
		1999	2000	2001	2002	1999	2000	2001	2002	1999	2000	2001	2002
Sweden (O-List)	1988	..	..	24	9	150	228	240	235	28.3	24.0	23.3	18.5
United States (NASDAQ)	1971	485	397	63	40[1]	4 829	4 734	4 109	3 725[1]	56.5	36.9	28.9	16.5
Canada (Canadian Venture Exchange)[2]	1999	2 425	403	330	122	2 358	2 598	2 688	2 504	1.7	10.2	12.7	9.7
Korea (KOSDAQ)	1996	160	250	181	176	453	604	721	843	22.0	5.6	9.5	5.0
Norway (SMB List)	1992	3	7	7	3	78	77	79	79	4.2	1.8	1.5	1.2
United Kingdom (AIM)	1995	67	203	109	78	347	524	629	704	1.5	1.6	1.2	1.0
Ireland (ITEQ)	2000	---	..	..	..	---	7	8	8	---	3.6	1.7	0.7
Italy (Nuovo Mercato)	1999	6	32	5	0	6	40	45	45	0.6	2.2	1.2	0.6
Germany (Neuer Market)[3]	1997	132	132	11	1	201	338	326	240	5.7	6.0	2.4	0.5
France (Nouveau marché)	1996	32	52	9	2	111	158	164	154	1.1	1.7	1.0	0.5
Switzerland (SWX New Market)	1999	6	11	1	0	6	17	15	9	..	3.0	0.9	0.2
Finland (NM List)	1999	..	..	..	..	..	17	16	15	..	0.7	0.3	0.2
Denmark (Dansk AMP)	2000	3	0	1	3	3	3	4	7	0.1	0.1	0.1	0.1
Spain (Nuevo Mercado)	2000	---	..	..	..	---	12	..	14	---	3.4	..	..
Japan (Mothers in Tokyo)	1999	2	27	7	8	2	29	..	..	0.2	0.1	..	..
Japan (Hercules in Osaka)	2000	—	..	43	..	—	..	32	..	..	..	0.3	..
Netherlands (EURO.NM Amsterdam)	1997	1	2	—	—	13	15	—	—	0.3	0.2	---	---

8Belgium (EURO.NM Belgium)	1997	6	3	---	---	13	16	---	---	0.2	0.2	---	---
Europe (EASDAQ)	1996	..	..	---	---	56	62	---	---	---	---	---	---
NASDAQ Europe[5]	2001	---	---	..	..	---	---	49	43	---	---	---	---
Austria (Austrian Growth Market)[6]	1999	..	..	---	---	2	2	---	---	0.01	0.01	---	---

Notes;

(1) End of October.
(2) Data includes both high-growth firms' shares and shares of investment funds.
(3) The Neuer Market segment will be discontinued after a transition period at the end of 2003.
(4) Previously NASDAQ Japan.
(5) In 2001, NASDAQ Europe acquired majority ownership in Easdaq.
(6) On April 2001, the two stocks in the AGM segment were transferred to the Specialist Segment of Wiener Börse.
Source: Compiled by OECD Secretariat from national sources.