Lund University International Master's Program in Environmental Science

MASTER THESIS

BIO-ENTREPRENEURIAL PARTNERSHIP – A TOOL FOR BIOTECHNOLOGY TRANSFER

A Systems of Innovation Approach

By

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Lund, Sweden
2004

To The Golden Generation Whose Shadows Hue The Horizons…

ABSTRACT

The current picture of biotechnology as a science suggests its potential for sustainable development, if to consider its environmental compatibility, economic viability and social responsibility. The geographical patterning of biotechnology capacity and utilization reveals the technology gap, 'genetic divide', between developed and developing countries. Due to institutional insufficiency, developing countries have lagged behind in the new bioeconomy. This thesis work attempts to find out and model the factors around this dilemma, and propose a solution to bridge this gap. The approach is made using the Systems of Innovation theoretical framework, to propose Bioentrepreneurial Partnership. Based primarily on 1. Public-Private sectors dialogue, 2. Reinforcement of R&D networks, and 3. Biotech start-ups and availability of funding i.e. VC, the solution is deemed to stimulate the necessary institutional change and, thus, the evolution of biotechnology in the countries, which have sought solace in development.

Key Words: sustainable development, biotechnology, genetic divide, bioeconomy, systems of innovation, entrepreneurship, bioentrepreneurial partnership.

ABBREVATIONS & ACRONYMS

BEP – BioEntrepreneurial Partnership

R&D – Research & Development

S&T – Science & Technology

NIS – National Innovation Systems

SI – Systems of Innovation

Biotech – Biotechnology (Sector)

Pharma-biotech – Pharmaceutical Biotechnology (Sector)

Agro-biotech – Agricultural Biotechnology (Sector)

USD – United States Dollar

IP(R) – Intellectual Property (Right)

GM(O) – Genetically Modified (Organism)

DNA – Deoxyribonucleic Acid

rDNA – Recombinant DNA

EUR – Euro (European Union's monetary unit)

WTO – World Trade Organization

bn – billion

mn – million

IPO – Initial Public Offering

VC – Venture Capital

PP – Private-Public

SD – Sustainable Development

Rs – Rupee (Indian monetary unit)

SME – Small and Medium-sized Enterprise

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1 - INTRODUCTION

The last several decades have been the yet oral history of biotechnology, after the advent of genetic manipulation techniques. As it has already proven, biotechnology is a source of welfare, promising to bring social well-being, economic growth and environmental friendliness, or sustainable development.

Today, biotechnology is practiced to a satisfactory extent only in a handful of developed countries – the big majority of the developing world, where it is the most sorely needed, is still far from its miracles. Bioentrepreneurship, which is central to formation of the bioeconomy, is the business of biotechnology or, stated otherwise, it is one of the main incentives for practice of today's commercial biotechnology. Developing countries have been out of the circle of the new bioeconomy, institutional insufficiency being one of the major reasons. This situation brings about the growing genetic dichotomy or, genetic divide, between poor and affluent nations.

Developing countries can indeed become good players in the new bioeconomy. However, of focal importance is reshaping of their national systems of biotechnology innovation via enhancement of foreign-assisted biotechnological partnerships. In other words, technology transfer should be favored from developed to developing countries. Critically, any approach towards this issue should be a win-win solution, for it to be viable in the long run.

I argue that Bioentrepreneurial Partnership stands promising to be such a solution. The concept is Systems of Innovation-premised, and significantly refers to corporate liaisons between private biotech sectors of interacting developed and developing countries. Since global bioentrepreneurship is predominantly in private hands, relations at this level seem promising to serve rapid build-up of biotechnology capacity and to unravel central bioeconomy-related issues that now seem to be biased against developing countries.

1.1 - Objectives

The prime objective of this thesis is to develop the abstract concept of 'BioEntrepreneurial Partnership', identify its main dimensions and substantiate its theoretical validity / feasibility, *without* testing its empirical relevance. There are a number of other objectives:

- To emphasize the function and potential of biotechnology as a contributor to sustainable development. A short survey into the field of biotechnology will be made, scrutinizing its major tools and industrial

sectors. Relevance of biotechnology to sustainability in this context is conceptualized in the intersection of societal, economic and environmental aspects.

- To briefly visualize the biotechnology market in terms of its structure and evolution. Importance will be given to the pharmaceutical and agricultural biotech sectors, which make up the biggest portion of the industry.

- To briefly study and present bioentrepreneurship as the main driver of the new bio-economy. Emphasis is drawn upon importance of private sector, indispensability of partnerships and alliances.

- To investigate the role and need of biotechnology in developing countries, and their current poor status in the new bio-economy in relation to 'genetic divide', which is problematized by means of a Causal Loop Diagram (CLD).

- To formulate the theoretical framework of National Innovation Systems (NIS) and identify its main parameters in relation to biotechnology innovation. Institutional innovation in this context will play a significant role.

1.2 - Materials and Methods

To carry out this study a thorough literature review has been done to retrieve updated information about the topic-related issues. Within the main sources used are books, international publications, appropriate legislative acts and reports. Personal correspondence with the effective figures of the field was made when either information was not available or new insights were necessary. Referencing to the used information sources is done in accordance with the most acknowledged academic writing guidelines.

To achieve a better understanding of the problem under question, function of its components, path of argument and relevance of the solution proposed, a systems analysis approach was utilized in the form of self-constructed CLD.

The thesis has a heavily theoretical character; all arguments are based on the Systems of Innovation theoretical framework. The mini case study of evolution of Indian biotechnology is done based on secondary data to supplement the analysis (Chapter 7).

1.3 - Scope and Limitations

For the purpose of comparison of statistics, figures from biotech industries of US and EU will be used. Figures from these sources are also used for extrapolations – thus, the differing factors for various countries are neglected. Where the most updated information was not available or accessible without extra cost, second updated version was used.

Endorsement of GMOs *per se* is not a purpose of this study, however, some GM features will be referred to as useful. Advantages and disadvantages of GMOs are thus neither discussed nor criticized. Though ethical issues and hazards of biotechnology are not addressed particularly, strict biosafety measures will be recommended.

Most assessments will be made according to pharma-biotech industry, because it accounts for the biggest portion of biotech industry. Projections will be made onto agro-biotech sector, which is newly growing. In doing so, shortcomings are not considered.

Due to time limitation and heavy theoretical orientation of this thesis work, the feasibility of BEP idea is not empirically tested and its limitations are not considered as such. Likewise, it may not respond to provide a satisfactory solution to all elements of the CLD. It needs to be further developed on country-specific basis considering the inherent features. The purpose of this study is to pioneer the idea.

1.4 - Thesis Structure

In the context of this thesis work, an interdisciplinary analysis is attempted; distant issues are brought together in relation to the topic. The thesis consists of 9 chapters, including references. To facilitate transition and understand the flow of arguments throughout the thesis, cross-references are made between chapters where possible.

2 – BIOTECHNOLOGY AND BIOENTREPRENEURSHIP

2A - INTRODUCTION TO BIOTECHNOLOGY

2.A.1 - Definition of Sustainable Development

Definitions of sustainability and sustainable development have frequently proved to be elusive. This study adopts the following definition:

Sustainable development: strategies and actions that have the objective of meeting the needs and aspirations of the present without compromising the ability to meet those of the future (Brundtland, 1987).

As implied by signatories to the Rio Declaration (UNEP, 2003), sustainable development is guided by the need for: *i)* better balance between conventional ideas of economic growth and the maintenance of environmental resources; *ii)* improved intra-generational and inter-generational equity in economic and environmental terms; and *iii)* ensuring sustainability in ways that have both local and global relevance. A closer look shows that a practice is sustainable when it is:

- **economically viable** - uses natural, financial and human capital to create value, wealth and profits.
- **environmentally compatible** - uses cleaner, more eco-efficient products and processes to prevent pollution, depletion of natural resources as well as loss of biodiversity and wildlife habitat.
- **socially responsible** - behaves in an ethical manner and manages the various impacts of its production through initiatives such as Responsible Care.

2.A.2 - Concept of Biotechnology

In a broad approach, biotechnology is defined as the "use of the cellular and molecular processes to solve problems or make products" (BIO, 2001). There exist several approaches for division of biotechnology into sectors. In the context of this thesis I will use the categorization proposed by Oliver (2000) who categorizes biotechnology into four different groups: human health care, agricultural, instruments and suppliers of lab products, and chemical and environmental.

Born already in the 1970s, biotechnology is still in its infancy and most of the opportunities it is to offer are still unrealized. An enabling technology, it has an increasingly important role in enhancing competitiveness, economic growth and environmental sustainability. Biotechnology, whose one of the

major tools is *recombinant DNA technology*[1], plays a significant role in the development of new products and production processes in the pharmaceutical, agro-food, and many other industrial sectors. A closer look at the three main branches of biotechnology is below:

Medical Biotechnology – deals with medical aspects of biotechnology. It has wide application in production of *pharmaceuticals*, complex biological molecules, which would otherwise be extremely difficult to synthesize. *Gene therapy*, which relies on interfering with genetic make-up of living organisms, is another application that holds potential to become an important strategy in the future to find innovative treatments to various inherited and acquired diseases. Among other technologies within the medical biotechnology field is *stem cell technology*; it lays on the premise of preserving the entirety of genetic make-up and guiding its ability to express itself for novel therapeutic applications. (EIB, 2002)

Agricultural Biotechnology - Applications of biotechnology in agriculture concentrate on the genetic modification of existing plant species to lower the cost of food production, to increase yield and to produce food of higher nutritional value. In this sense, genetic modification means implantation of genetic material from other species into the genetic make-up of the plant species manipulated, where traditional crossbreeding methods fail to function. To make a distinction, applications here fall within one of two broad categories:

a). *Facilitating plant treatment* for the farmer via herbicides, in-built pest resistance or stress tolerance to make plants easily take over weeds, resist pest invasion and survive in hostile climate conditions respectively;

b). *Enhancing nutritional value* for the final consumers' benefit via mainly developing 'novel foods' with increased concentration of essential nutrients; and neutraceuticals, food having therapeutic value. (EIB, 2002)

Chemical and Environmental Biotechnology – Applications here are to favor *sustainable industrial development*: continuous innovation, improvement and use of cleaner technologies to make fundamental change in pollution level and resource consumption. Biotechnology enables this via rapid and controlled production of biodegradable polymers and biocatalysts, which produce fewer by-products, can start with

[1] The technology of preparing recombinant DNA in vitro by cutting up DNA molecules and splicing together fragments from more than one organism (yourdictionary.net)

less purified feedstock, and are self-propagating. Thus, biotechnology offers new approaches that are needed to manage increasing industrialization and urbanization in a sustainable way. (EIB, 2002)

2B - BIOTECHNOLOGY MARKET

Biotechnology is an intersection of various industries. Applications in pharmaceutical, agricultural and environmental fields constitute the most voluminous fractions of the total biotechnology market, with respectively decreasing strengths. For illustrative purposes, Table 2.1 shows figures for the year 2000 of biotechnology market and its year-by-year increase in itself and in the total market.

	Market for Biotechnology (USD bn) in 2000	Average growth rate y-o-y (1995-2000), %	Biotechnology products as % of total market	Average growth rate y-o-y of total market (1995-2000), %
Pharmaceuticals	17,0	20	4,8	8
Agrochemicals and Seeds	7,5	5	18,0	1
Environmental Remediation	<1,0	n.a.	<10,0	n.a.
Others	<0,5	n.a.	<0,1	n.a.
Total	ca. 26,0	ca. 15		

Table 2.1: Main sections and volumes of the global biotechnology market for the year 2000. Source: EIB, 2002

Regional patterns of pharmaceuticals sales reflect that North America accounts for approximately half of total sales, Europe for 25% and Japan for 16%. Biopharmaceuticals[2] is so far the largest segment with market capacity of about USD 17 bn in 2000. In contrast, the segment for GM crops and pesticides is smaller with a volume of less than USD 8 bn. These figures are followed by environmental applications that hardly reach USD 1 bn. In total, with a market estimate of USD 26 bn, biotechnology-based products grow faster than the rest of the market. (EIB, 2002)

2.B.1 - Pharmaceutical Biotechnology

Pharmaceutical biotechnology is considered as the deliverer of innovative solutions to the growing medical demand from the aging population in the developed countries and insufficient healthcare in the developing ones. Biopharmaceuticals being the main driver of this growth, the field is believed to stay a

[2] Complex macromolecules created through genetic manipulation of living organisms using rDNA techniques. (strategis.ic.gc.ca)

highly dynamic and R&D-intensive market. Breaking records, they noted a growth of at least 20% per year between 1995 and 2000, compared to 7% and 11% for pharmaceutical sales in general. For the year 2000, pharmaceutical companies spent approximately 16% of their total sales on R&D, which makes up almost USD 55 bn. With an increasing trend, a considerable fraction of this expenditure is being allocated to clinical trials[3]. (EIB, 2002)

Biotechnology, when practiced correctly, can be regarded as a sustainable practice in terms of economical viability. Summarized below are the main economic contributions of the biotechnology sector to US economy in 2000, as reported by E&Y (2001):

- "437,400 jobs in US, of which 150,800 were generated directly by biotechnology companies and the remaining 286,600 by both companies supplying inputs to the industry and providing goods/services to biotechnology employees.

- USD 47 bn in additional revenues, of which USD 20 bn accounts directly for biotechnology companies and USD 27 bn for companies supplying inputs or selling goods/services to biotech employees.

- USD 10 bn in tax revenues, including federal, state and local taxes with the largest components of the tax revenues in individual income taxes, social security and property taxes."

2.B.2 - Agricultural Biotechnology

Agrochemicals and high-value seeds constitute the main two halves of the agricultural biotechnology market, which totaled USD 43 bn globally in 2000. This figure makes up approximately 40% of the global pharmaceutical market. Geographic regions that lead the pharmaceutical biotechnology market hold their positions here as well: North America makes up roughly 40% of the total, Europe accounts for about 30%, Asia and the Pacific region for 15% and Latin America for 13%. (EIB, 2002)

Agricultural biotechnology, however, requires lower levels of R&D expenditure: it makes roughly 8% of total sales for the industry. Similar with pharmaceuticals, considerable costs are consumed by field tests and approval procedure. Despite this, the prospects for biotechnological applications in agrochemicals and seeds are bright: GM crops and related pesticides are predicted to grow strongly at more than 5% per

[3] Refer to chapter 2.C.2

year. The total market for GM crops and pesticides is estimated to grow up to USD 10 bn by 2005. (EIB, 2002)

Regarding the economic contributions of the agro-biotech sector, E&Y (2001) reports the following:

- "Agricultural biotechnology generated 21,900 jobs and about USD 2.3 bn in revenues, including the contributions of companies supplying inputs to the industry or goods/services to biotechnology employees."

2C - BIOENTREPRENEURSHIP

2.C.1 - World Outlook

Bioentrepreneurship is not homogenously practiced throughout the world, unlike the consumption of biotechnology-derived products. It occurs mostly in the United States and Canada, with Europe recently closing the gap, and Japan a very distant third. The list continues with Australia, Hong Kong, Korea, Singapore, and lately China and India. (Persidis, 1997; Littlejohn, 2002) For illustrative purposes, this chapter will draw heavily upon statistics of US and EU biotech sectors.

Analysis of where biotechnology is happening indicates where most new knowledge is being created. One of such indicators is the sale of advanced laboratory hardware and research reagents. EuropaBio (1997) survey found out that 55-60% of these is sold in North America, 25-30% in Europe, 10% in Japan, and the remaining 5% in other countries. In addition, of all biotechnology drugs being developed, 63% are in North America, 25% in Europe, 7% in Japan, and 5% in the rest of the world. Also, it is estimated that 45% of all biopharmaceuticals are sold in the US, 28% in Europe, and 37% in the rest of the world combined. (EuropaBio, 1997; Persidis, 1997) Examination of the numbers of issued patents in this field provides a further indication of global activity in biotechnology research. Of total biotech, drug and human DNA patents, USA ranks first, followed by Europe, and then Japan.

Based on the total number of companies, Europe holds the leading position in the field. As of late 2000, numbers of registered dedicated biotechnology companies are 2,104 in Europe and 1,379 in the United States. (BIO, 2001; BID, 2001)

2.C.2 - Driving Forces and Necessities

The EuropaBio (1997) survey of pharmaceutical companies identified 10 factors that, to varying degrees, directly affect biotechnology investment decisions and strategic choices of biotech companies. It seems that the most important factors affecting decisions to invest in particular biotechnologies are the scale of the market opportunity, coupled to strong patent protection and favorable regulatory environment, as shown in Table 2.2.

Factor	Percentage of companies that believe factor is important
Market Opportunity	100%
Patent Protection	85%
Regulatory environment	60%
Competitor Pressure	60%
Consumer Acceptance	55%
Availability of Skilled Labor	40%
Technology Transfer Mechanisms	35%
Availability of Equity Capital	20%
Scale and Quality of Public R&D	15%
Access to Innovative Suppliers	8%

Table 2.2: Factors affecting investment decisions. Source: EuropaBio, 1997

Market conditions, demand and supply, and consumer attitudes are among the prime ones. Additional key factors include government fiscal policies as they relate to biotechnology, in particular tax requirements on capital gains and R&D tax exemptions. (Persidis, 1997) Some of these factors will be discussed in the further chapters.

2.C.3 - Financial Resources and Availability

Equity funding[4] is the most dominant funding mechanism of the global biotechnology industry. With its drastic increase over the last several years, other forms of finance such as debt or public funding in forms of subsidies or research contracts have become recessive. (BIO, 2001) The table 2.3 shows a breakdown of the development of equity financing in biotechnology in US and Europe.

In terms of volume of equity funding, US holds the first place against Europe, which is less dependent on stock market finance. Proportionate with growing stock markets, the amount of equity raised by US biotechnology companies has expanded considerably with EUR 414 mn compared with EUR 33 mn for

[4] An investment, which combines mutual fund shares and a life insurance policy. (investorwords.com)

TYPE OF EQUITY (EUR bn)	EUROPE		US		TOTAL	
	2000	1999	2000	1999	2000	1999
IPOs[5]	3,0	0,3	6,7	0,6	9,7	0,9
Capital increase and others	2,4	0,2	23,2	4,3	25,6	4,5
Venture capital	1,2	0,6	3,2	1,4	4,4	2,0
Total	**6,6**	**1,1**	**33,1**	**6,3**	**39,7**	**7,4**

Table 2.3: Development of equity financing in biotechnology. Source: E&Y European Life Sciences Report, 2001

European start-ups, which depend heavily on other forms of equity financing such as VC and private equity. For European biotechnology, in the sectors where public interest and infrastructure are involved, public funding becomes available as an alternative source of financing, to complement private industrial activity. (EIB, 2002)

2.C.4 - Biotech Business Models

Since the growth of the practice of bioentrepreneurship there has been a debate over the business models according to which biotech companies are categorized. Companies decide either to develop products or technology and tools, or both – the former is referred to as 'vertical' and the latter as 'toolbox' companies. (Formela, 1998)

Technology development and drug discovery in particular have become a time- and money-consuming business. Figure 2.1 depicts the phases of drug development process on the time scale. In the *discovery* phase, new drug molecules are discovered using biological and chemical techniques. *Pre-clinical* phase concerns the testing of a drug candidate in laboratory conditions, which gives way to Investigation of New Drug (*IND*) application for permission to try a new drug on human patients. During the clinical trials of *Phase I*, *II* and *III*, the drug candidate is tried on respectively increasing number of human patients. After this, application to authorities for New Drug Application (*NDA*) is made. Drug candidates having successfully passed all tests launch the *Market* phase. It is noteworthy that as drug development proceeds in phases, expenses born rise geometrically. Thus, for a single drug to be discovered and fully developed, it requires approximately in range of USD 500 mn and 1 bn. Taking between 12-15 years for a drug to be developed, time to reach the profit before patent expiry reduces considerably, jeopardizing the profitability prospects of the whole process. (King, 2003)

[5] A company's first sale of company stock to the public (investordictionary.com).

Under the influence of these facts, pharmaceutical companies take their functional positions in one, or several, or all of these steps of drug discovery and development, according to their financial strength and, thus, the level of risk they afford to assume. This, make companies specialize in one of the business models, described in the Table 2.4.

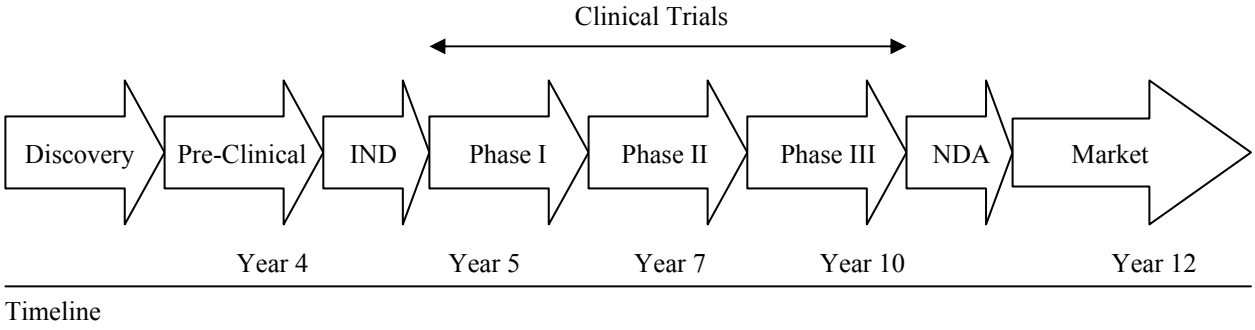

Figure 2.1: Phases of drug development process. Source: Halioua, 2002.

Business Model	Description
Provide Services	Provide services for a client typically on a fees-for service basis
License Technology	License proprietary technology to companies for very specific use
Early Stage Collaboration	Develop lead candidates[6] and license to third party for further development following Phase I or II
Late Stage Collaboration	Develop lead candidates and license to commercialization partner following Phase II and III
Virtually Integrated Pharmaceutical Company – VIPCO	Companies that own the compound, but all development is outsourced and compound is later partnered for commercialization
Fully Integrated Pharmaceutical Company - FIPCO	Develop targets and lead candidates internally and sell via internal or contract sales force

Table 2.4: Biotechnology business models and their descriptions. Adopted from Halioua, 2002.

Big pharmaceutical companies fitting into the FIPCO and VIPCO models (see Table 2.4) are highly integrated businesses, which afford to cover a great deal of drug discovery and development process. Once they rich the level of circulating positive finances in their systems, their focus shifts to stabilizing a

[6] A compound or substance that is believed to have potential to treat disease (ppdi.com)

profitable and stable growth on the expense of simultaneously making new blockbuster drugs[7] and filling the gap of patent expiry with new products from R&D. (EIB, 2002)

2.C.5 - Biotech Alliances

Facing these facts, big pharma companies spread the risk of drug development via engaging into alliances[8] with small innovative biotech firms, which sell their expertise to identify new products or to support enabling technologies. Thus, small companies can focus on innovative drug discovery, while big ones on marketing and distribution. Currently, as much as 20% of R&D expenses of big pharma companies are spent on alliances. Figure 2.2 shows the year-by-year increase in the number of such alliances, which are valued for USD 15 bn. (EIB, 2002) Alliances in the agro-biotech arena are predominated by mergers of agrochemicals and high-value seeds businesses. Differently, these alliances target at integration of the whole agro-chain into one 'from-gene-to-supermarket' company. (Zilberman *et al*, 1997)

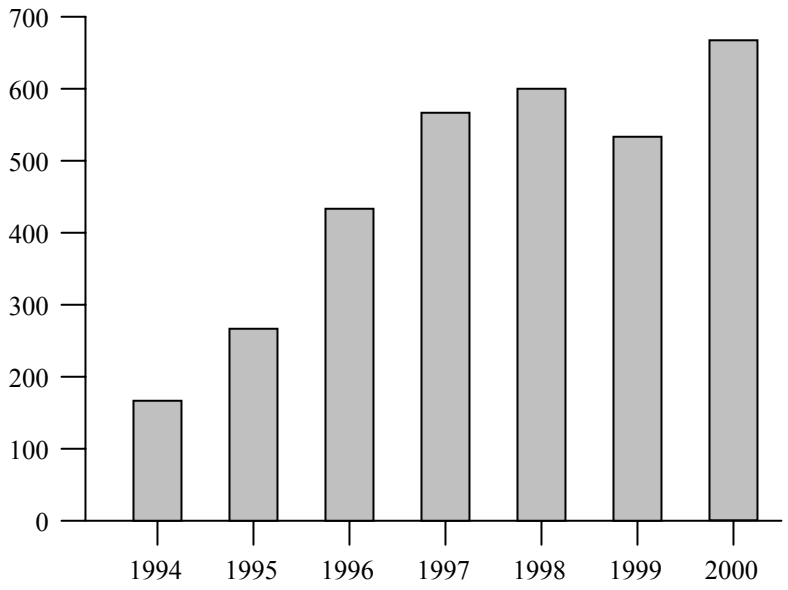

Figure 2.2: Numbers of pharma-biotech alliances according to years. Source: Halioua, 2002

Hence, innovative activities will be more concentrated within small companies, with start-ups being the most important part. It seems that the resource-intensive work of invention, innovation and knowledge creation is likely to be increasingly transferred to the smaller players.

[7] Referred to drugs generating revenue of over USD 1 bn a year (businessweek.com)
[8] Also known as *mergers and acquisitions*.

3 - THEORETICAL FRAMEWORK

The concept of Bioentrepreneurial Partnership has not been addressed *per se* in the related literature, or, more specifically, it will be coined and developed in the context of this thesis. The very complex nature of the concept necessitates utilization of a theoretical framework that is able to embrace its most aspects. Attempting to do so, I have drawn heavily upon *Systems of Innovation* (SI) approach.

A comprehensive review of SI as a theoretical framework has been elaborated by Edquist (1997) in his book titled *Systems of Innovation: Technologies, Institutions and Organizations*. Although the SI approach is not always considered a formal and established theory, its development has been influenced by various theories of innovation such as interactive *learning*, *institutional* and *evolutionary theories*.

Nelson *et al*'s (1993) definition to *innovation* is among the recent ones – they refer to it narrowly as 'technical innovations'. However, one of the very early founders and contributors to this notion, Schumpeter (1939) offers a broader definition: "We will simply define 'innovation' as the setting up *new* production functions. This covers the case of a new commodity as well as those of a new form of organization such as a merger, of the opening up of new markets, and so on. Recalling that production in the economic sense is nothing but combining productive services, we may express the same thing by saying that innovation combines factors in a new way, or that it consists in carrying out New Combinations."

According to Elam (1993), Schumpeter's *Theory of Innovation and Entrepreneurship* finds continued relevance in the study of systemic patterns of innovation. He also states that Schumpeter's definition of innovation as 'carrying out of new combinations' remains as appropriate as ever today; it is just that the new combinations in question have grown significantly in scale and complexity, calling forth *new modes of entrepreneurial action*.

Thus, Schumpeter argues importance of innovation to economies and emphasizes the interplay between agents, institutions and markets in innovation. This view opposes the 'linear' view of innovation, where basic research is doomed to lead to applied research and further to new products and processes in order to end up in 'welfare'. (Edquist, 1993)

Critical to the SI argument is the concept of 'national systems of innovation'. Freeman (1987) defines it as "the network of institutions in the private and public sectors whose activities and interactions initiate, modify and diffuse new technologies". Later, Lundvall (1992) broadens this definition as: "All parts and

aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring – the production systems, the marketing system and the system of finance present themselves as subsystem in which learning takes place."

Technology is the central factor considered to innovation. Whilst, together with technological development it forms a complex and interconnected system, it is developed by companies' R&D system within the context of the public-sector research arrangement, and it functions as the innovative factor in society, thus, creating economic growth. Herein, the R&D system and science are complex social systems: technology forms both parts of products, with product innovations, and the means of production, with process innovations. (Sundbo, 1998)

Similar to the SI approach, international attention has drawn 'technological systems' idea of Carlsson *et al* (1991), which is defined as "a network of agents interacting in specific economic / industrial area under a particular institutional infrastructure or a set of infrastructures and involved in the generation, diffusion and utilization of technology". Beside the 'national' dimension of SI, Edquist *et al* (1993) have added the 'sectoral' and 'regional' dimensions, which make the SI a truly interdisciplinary approach. Thus, the 'technological systems' argument is 'sectoral' in the sense that it is determined by generic technologies; they can be restricted to one industrial branch.

'National' Systems of Innovation can function as a framework for the formulation of policies and strategies - important implications for government policies and firm strategies on R&D, innovation, education and training are inherent in it. Another vital point within this approach is that the conditions are unique in various existing innovation systems. (Edquist, 1994)

To shift the focus, Schumpeter positions innovation in the center of his *Theory of economic development.* He attributes innovative success just to the specific feature of entrepreneurship of outstanding individuals in an economy. Backing on Schumpeter, Sundbo (1998) defines *entrepreneur* as "a creative person who, not necessarily being an inventor, creates new products and new markets by means of new combinations of the factors of production". Sundbo also states that entrepreneurs are neither managers, nor capitalists – in fact, they run a limited risk. Schumpeter's central figure, entrepreneur, has a fundamental function in the dynamics of the economic system and is the determinant behind socio-economic growth. *Entrepreneurship*, the practice of being an entrepreneur, is not a profession and not a permanent state. (Sundbo, 1998)

It is becoming increasingly recognized that modern technical solutions are characterized by an increased interrelatedness between heterogeneous actors and knowledge fields. No single firm can keep pace with the development of all relevant technologies. Therefore, firms seek access to external knowledge sources. *The theory of the firm*, in this sense, has been challenging new economists to seek novel solutions in the *innovation networks*. (Holmström *et al*, 1988). According to Zuscovitch *et al* (1995): "Networks represent a mechanism for innovation diffusion through collaboration and the interactive relationship becomes not only a cooperation device to create resources, but an essential enabling force of technical progress". Some authors also draw upon *Game Theory*, trying to extend Prisoner's dilemma to explain feasibility of cooperative know-how exchange between firms in above-mentioned innovation networks. Clearly, firms need to play win-win games in the cooperation-competition environment to keep up with the dynamic pace of innovative survival. (Pyka, 1999)

A strand of dual discussions in the SI context has been around 'inducibility' and 'endogeneity' of technological change. It is argued that it is the market demand that stimulates inventive activity (to induce advances in technology) rather than the state of knowledge – this makes up the Griliches-Schmookler 'demand pull' model. However, careful industry studies, such as the study of innovation in the chemical industry by Walsh (1984), suggest that both "supply and demand factors play an important role in innovation and in the life cycle of industries, but the relationship between the two varies with time and the maturity of the industrial sector concerned". (Edquist, 1993) Rosenberg (1976) was able to state that: "Not too many years ago most economists were content to treat the process of technological change as an exogenous variable. Technological change – and the underlying body of growing scientific knowledge upon which it drew – was regarded as moving along according to certain internal processes or laws of its own, in any case independently of economic forces… …it is now coming to be regarded as something which can be *entirely* explained by economic forces."

Thus, technological change is endogenous to the economic system and the industry. Through these discussions, it can be concluded that innovation can be realized in societies, which have the necessary social institutions, networks and outlook to take advantage of these. A system of innovation consists of a network of economic agents together with the institutions and policies that influence their innovative behavior and performance. Innovation, which rests on the creation of knowledge, increasingly takes place at the interface of formal research and economic activity, thus denying the primacy of either knowledge creation and validation institutions (R&D bodies, universities, etc) or knowledge application institutes (usually enterprises). Rather, it is partnerships between these types of actors that are important. (Lundvall, 1992)

4 - NEW BIOECONOMY AND GENETIC DIVIDE

Technology is generated to solve particular problems and to address development. It passes through the stages of adoption, adaptation and diffusion. Its products are then made available for consumption through market or non-market mechanisms. Juma *et al* (2000) state that: "When new technologies are generated, though primarily for developed country markets, which are useful for or have the potential to be successfully adapted to address important human development needs of the impoverished, it is clear that the international community should do its best to see that such technologies and products become disseminated in the developing world. This objective can be achieved by diffusion of technologies."

Evidence from a number of sectors illustrates the dynamics associated with the product cycle approach to global technological development. In the area of health particularly, it has been recorded that very little R&D being done by the private research-based pharmaceutical industry is done on diseases rampant in the developing world, such as on tropical diseases (Kremer, 2000). Motivated by profit, there are no incentives for the pharmaceutical industry to develop such medicines.

Table 5.1 shows several disease categories and their relative importance in both developed and developing countries' markets. The table uncovers the stark differences in the pharmaceutical R&D priorities of the two worlds. In the developing world, research-based pharmaceutical companies concentrate more on, for instance, disease conditions such as cardiovascular, cancer or diabetes, which are clearly not the priorities for the developing world, whose global share of these diseases is less than 10%. (Juma *et al*, 2000)

Selected Disease Categories Share of Market in Rich Countries & Importance in Poor Countries		
	Rich Countries' Expenditure-Weighted Share	**Poor Countries' Share of Disease**
Cardiovascular	91%	10%
Cancers	94%	5%
Diabetes Mellitus	96%	1%
Infectious & Parasitic	38%	21%
HIV/AIDS	49%	6%
Malaria	0%	4%

Table 4.1: Selected disease categories and their importance in developed and developing countries.
Source: Juma *et al*, 2000

In agro-biotech sector as well, new technologies are increasingly being developed only in a few developed countries. Over the 1996-2000 period 85% of global transgenic crops were growing in the industrial countries. According to James (2000), approximately 99% of the world's transgenic crops are

grown in the USA and Canada, Argentina and China. The share of transgenic crops grown in developing countries has risen consistently from 14% in 1997, to 16% in 1998, to 18% in 1999 and 24% in 2000. In fact, the area of transgenic crops is growing faster in the developing world than in industrialized nations, however, the coverage of transgenic crops is limited to a small number of countries with relatively similar ecological conditions (Aerni *et al*, 2000).

Juma (2001, forthcoming) has modeled the concept **'Genetic Divide'** in association with as-such uneven distribution of biotechnological capacity between the rich and poor nations. As he argues, overcoming this will require a shift from the 'product cycle model' to 'market inclusion model' that includes developing countries as users of biotechnology and not mere consumers of final products. This will be a true challenge to the ability of globalization to generate win-win solutions for the generators of the biotechnology and its subsequent users around the world.

Juma *et al* (undated) define the **New Bioeconomy** and its institutional characteristics as: "The New Bioeconomy is the confluence of modern biotechnologies and the market niches they occupy. It is characterized by the emergence of institutional structures that demand alternative technology cooperation approaches. ***First***, the new bioeconomy has emerged concurrently with international trading rules that reinforce the market dominance of leaders in particular technological fields. These rules are reinforced by greater emphasis on instruments such as the Agreement on Trade-related Intellectual Property (TRIPs) under the World Trade Organization (WTO), which reduce the prospects for technological spillovers to developing countries. ***Second***, globalisation has intensified interactions among firms in the developed world and contributed to technological convergence among firms in this region at the expense of linkages with firms in developing countries. ***Third***, the new bioeconomy is driven largely by the private sector, with lesser participation of public sector enterprises. The growing role of the private sector in the industrialized countries demands a similar shift in the developing countries."

On the whole, a new technology governance regime is needed to foster technological cooperation, expand market opportunities, expand the prospects for wider acceptance of biotechnology products and enhance biotechnology capabilities in developing countries. Hence, shifting from such linear approach to one that takes into account the diversity of competencies around the world as well as the need to bring developing countries into the new bioeconomy through enhanced biotechnological capacity requires significant changes in the existing system of global governance. (Juma *et al*, 2000) It can be achieved through synergy of national innovation systems.

4.1 - Causal Loop Diagram

Previous discussions elucidate that 'genetic divide' and, equivalently, poor participation of developing countries in the new bioeconomy can be overcome by creating a global biotechnology governance regime. The CLD (figure 5.1), prepared according to the reasoning of Juma *et al* (undated), shows the four main factors (prerequisites) of such a regime and their interplay. It is constructed so that to represent an ideal case where all the factors enhance 'participation in bioeconomy'.

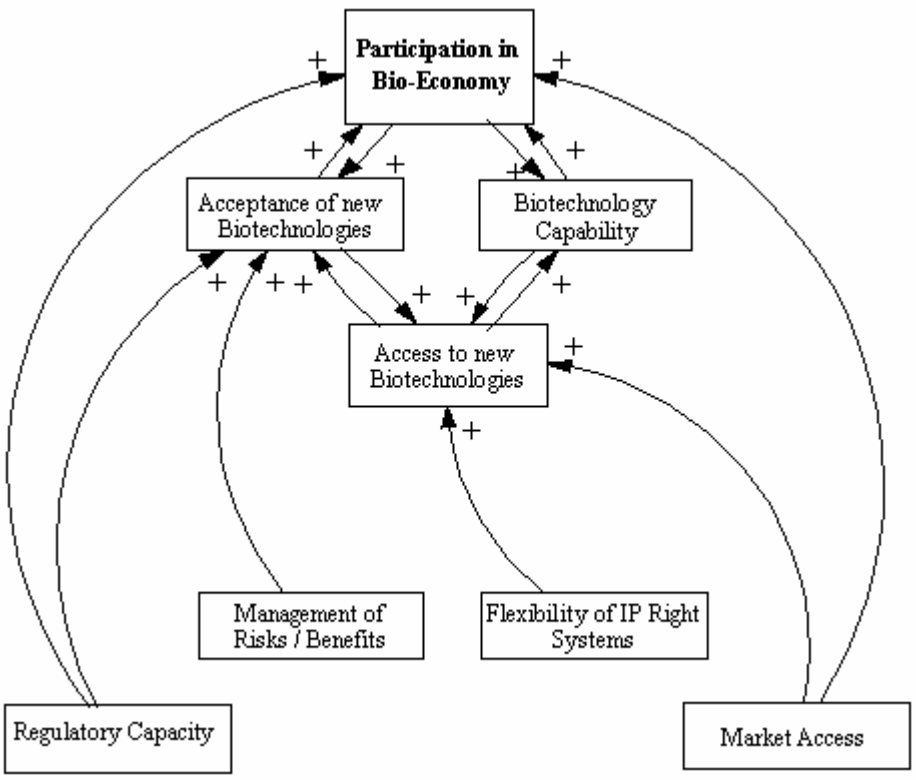

Figure 4.1: Causal Loop diagram (CLD) representing the main relationships between the prerequisites of the global biotechnology governance regime.

Market access

Technology access and acceptance are two factors that are affected by market access, which appears to be essential for international trade and market liberalization. Despite the fact that liberalization of markets has increased over the last 50 years, many barriers to trade still exist – main ones of them are high tariff[9] peaks, tariff escalations and standards. This is especially true for labor-dependent sectors that are indispensable for developing countries. Agricultural and industrial product exports to developed countries

[9] A government tax on imports or exports (thefreedictionary.com)

suffer most from tariff peaks, which dramatically hamper the incentives in developing countries to export finished products, thus, reducing diversification and skill accumulation. Regarding standards, exporters are required to meets well-defined product criteria found in the importing countries – an important element of international trade (Maggi *et al*, 2003). Thus, importantly due to these reasons, most developing countries continue to be marginalized in international trade. (Juma *et al,* undated)

SICE (2003) defines a way to cope with the dilemma: "To fashion a free trade arrangement and to introduce business facilitation measures intended to enable more effective commercial interaction across borders, there must be an across-borders trend of reduction in tariffs, tariff peaks and associated escalation practices especially in the areas of agriculture and associated subsidy protection. The key to any approach to the tariff issue is the *harmonization* of tariff targets. For developing countries the most positive implications of any free trade arrangement is that trade liberalization and all its accouterments result in more pronounced market access arrangements to larger markets. Ultimately, as far as the market access objectives of the developing countries of the OECS are concerned they will rest in securing lifting of market access barriers in developed country markets for products originating in developing countries." This issue needs to be addressed by institutional innovation in the context of the new bioeconomy.

Flexibility of intellectual property systems

IP protection is one of the key attributes of biotechnology. Without the existence of an IP regime that provides comfort to investors and inventors alike, complementary institutions such as VC would not have evolved to the extent they did. In this regard, IP protection has evolved together with the biotechnology industry. (WBCSD, 2002)

Impact of IPRs in biotechnology on developing countries' participation varies depending on the nature of the research, level of technological development and enterprise size. Joining the TRIPs agreement is a potential opportunity to access the patented technologies for developing countries, which are in the early stages of technological learning. Access to new biotechnologies will clearly build up their technological capabilities, generate trust to and increase national acceptance of these technologies. (Juma *et al,* undated)

The TRIPs agreement acknowledges technology as a contributor to social and economic welfare in Article 7 as: "The protection and enforcement of intellectual property rights should contribute to the promotion of technological innovation and to the transfer and dissemination of technology, to the mutual advantage of producers and users of technological knowledge and in a manner conducive to social and economic welfare, and to a balance of rights and obligations." Developing countries come to advocate

that the TRIPs agreement positively affects their ability of use technological knowledge to promote public interest goals such as health, nutrition and environmental conservation, and they plea for broadening of the regime of IP protection to other products to promote more intensive technology transfer and, thus, greater domestic innovative activities. (Juma, 1999)

In words of Juma *et al* (undated): "Developing countries need to ensure that they meet the minimum requirements for intellectual property protection and create suitable institutional environment for inventive activity. In turn, they need to increase the level of trust and flexibility in the intellectual property system, seeking to balance strong intellectual property protection with the need to broaden the base for technological partnerships with developing countries." Still, this is to be addressed via successful rearrangement of national innovation systems.

Regulatory Capacity

The regulatory issues that are brought under the heading of the new bioeconomy concern institutional measures that are designed for adjustability of national technological set-up in general, and facilitation to adopt new biotechnologies in particular. Trustable and stable regulatory system is a necessity if a country's participation in the new bioeconomy is at stake. It directly affects a country's internal attitude to S&T, especially in commercial sense, and also external investment decisions. Acceptance, adoption and implementation of new technologies are likewise facilitated by favorable regulatory milieu.

The second issue relates to GMOs – about their international trade and the safety of biotechnology research. Juma *et al* (undated) recommend that: "Previous experience from the implementation of the Cartagena Protocol on Biosafety shows that building regulatory capacity for biotechnology requires considerable external assistance for most developing countries. In order to promote the use of new biotechnologies, enabling and encouraging set of policy initiatives need to be considered and implemented". This fact suggests that the growth of regulatory capabilities in developing countries necessitates concerted action in the intersection of national innovation systems.

Management of risks and benefits

Technologies are prone to be accepted by a society if its potential risks are reduced and benefits preferably enhanced. Likewise, in the absence of measures that reduce risk of adoption of new technologies in developing countries, resistance to them is likely to emerge and undermine the potential benefits to their societies. (Juma *et al,* undated)

The issue is about the risk associated with the development of new biotechnological products. As mentioned in the previous chapters, product development in biotechnology is a lengthy process, which requires capital investment and includes uncertainly – the risk is inevitable. Since the last several decades the construction of uncertainty in relation to investment decisions on R&D for research-intensive industries changed from a combination of dramatic shifts in the regulatory environment and in the nature of industrial organization. (Lawton Smith, 2000) In author's own words, five trends can be observed: "First, restructuring in the regulatory environment has comprised a general tendency towards de-regulation. Second, there has been an increase in the number of national regulatory institutions as countries switch from state ownership towards a more US style of governance through regulation. Third, the drive towards both harmonization of regulation and to increase competition has also resulted in an increase in regulatory bodies. Fourth, there has been a greater focus on the region as a significant deliverer of innovation support strategies. Fifth, in industry there has been a growing tendency towards merger and collaboration between major companies in order to reduce the costs and risks associated with rapidly rising costs of R&D and increasing competition."

Partnership strategies and alliances await being designed to alleviate the uncertainty, and favour the search for and utilization of new biotechnologies. In doing this, particular attention deserve developing countries. It is therefore recommended that partnership models that are relevant to developing countries be identified and promoted as a part of the expansion of the new bioeconomy.

5 - BIOTECHNOLOGY TRANSFER

Despite the fact that S&T have existed for a long time now, the novelty is sharing of scientific knowledge and its rapid utilization in meeting concrete human needs. UN's Agenda for Development (1997) urges that developing countries develop and strengthen their capabilities to generate and exploit technology to solve production problems, feed their population, care for the health and education of their people, and do so in a sustainable way. The prevalent situation of S&T in the developing world reveals the issue as to what degree alliances, strategies and mechanisms are best suited to harnessing S&T for development throughout the developing world.

According to UNCSTD (1999), in the industrialized countries of the North, in contrast to the developing countries of the South, developments in bioscience and biotechnology are characterized by increasing specialization of R&D; accelerating diversification of knowledge and skills, and a progressive decentralization of research capacities. It also states that: "The dynamics of these developments present the 'danger' that 'genetic divide' will get more pronounced. Therefore, strengthening research capacities in developing world, pooling resources through various forms of North–South and South–South research cooperation, and improving global access to the scientific research information that is available in the North, have been given high priority on international policy agendas." Globalization and liberalization present a wide range of options and opportunities for developing countries. Many of these countries can seize these opportunities through increased cooperation in S&T.

Research networks as an organizational mechanism for linking scientists and institutions that are committed to sharing information and working together, are increasingly regarded as an important policy instrument to close the research gap between the North and the South. The UN Commission for Science and Technology for Development has therefore identified North–South research networks as one of the issues to be addressed in its "Common Vision for the Future of S&T for Development". More recently, South–South research networks have emerged. The available evidence suggests that South-South cooperation received its first practical impetus from the motivation of increased trade and investment. These networks aim to make optimal use of complementarity and economics of scale and scope, predominantly at the regional level. (UNCSTD, 1999)

Biotechnology in particular, when it comes to the evaluation of the impact of this collaboration effort on developing countries, it is often pointed out that far too many research projects are still managed from outside the developing countries and are highly dependent on donors' finances and good will. Such research networks arose in the 1970s, when this organizational mechanism for linking scientists and

institutions became a tool for donor agencies for implement their research policy agendas. Among such networks are Agricultural Research and Extension Network (AGREN), Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), Rural Development Forestry Network (RDFN), Consultative Group on International Agricultural Research (CGIAR), Cassava Biotechnology Network and many others. These networks can only sustain themselves as long as the donors continue their support; consequently, much of their efforts are directed to securing this support. In the light of the declining budgets of donor agencies, the financial sustainability of these research networks has become an important issue for technology transfer mechanisms - here, biotechnology transfer. (UNCSTD, 1999)

Thus, biotechnology transfer mechanisms as such, irrespective of their motives, are frequently supported by a formal framework and budget, provided from the North, if only because researchers and institutions in developing economies are unable to respond without such resources. To the contrary of North-only partnerships where industry is actively involved in research funding, generation and exploitation, in North-South partnerships its role is negligible. As UNCSTD (1999) states: "This is true for a number of reasons, the best-known being the fact that historically neither national private enterprises, nor multinationals' subsidiaries in developing countries invest in research locally. This trend has become even more evident in the globalized world with the privatization of state-owned enterprises, which had active R&D facilities, the de-nationalization of the few innovative national companies and the merging of multinationals and the relocalization of their R&D facilities. Consequently, R&D in the South tends to emphasize research (!) and to be located in public universities and government institutes."

Although lagging behind, collaboration is on the rise in the private sector as well – as indicated by the increase in the number of formal cooperative agreements between firms, the growth of overseas R&D activities performed under contract and through subsidiaries, and the increase in the number of R&D laboratories located abroad (OECD, 1998). Studies also show very clearly that collaboration between business and non-business entities is rising, that the share of R&D performed by the higher education and government sectors and funded by the business sector is increasing and, most significantly, that production of scientific research and technological know-how depends on research conducted in other countries (Leo Velho, 2002).

In line with increasing global biotechnological change, the range of knowledge required for specific innovations also expands. The need grows for strategic alliances and network structures to increase the pool of knowledge available and to reduce the risks to each individual partner. International R&D collaboration among the advanced countries is driven by pragmatic motives and aims at direct benefits for

all involved. Among these are access to complementary expertise, knowledge or skills to enhance scientific or technological excellence and sharing costs and risks of uncertain and expensive R&D activities - linked to innovation objectives. Such innovation-generating incentives need to be extended in the developing countries too, to stimulate their innovative behavior and to gear up their contribution to the growing bioeconomy. (Juma, undated; UNCSTD, 1999)

While the strengthened rationale may establish a need and identify potential benefits of continued S&T cooperation, technology transferors and transferees increasingly agree that the ideas are too technical and lack the power to inspire and move people in the way that the earlier motivating ideas for cooperation did. Thus, the development of a new technology transfer vision is also important. Such initiatives would require new forms of R&D and commercial partnerships.

5.1 - A New Vision

There is a growing consensus that the current modes of biotechnology transfer into developing countries in the form of North-South and South-South cooperation are no longer sufficiently inducing innovative behavior and tackling the developmental issues in developing countries. In the face of the expanding 'genetic divide', there is an urgent need to change or accompany the existing routes of biotechnology transfer with more comprehensive and more viable tools. The need for change is mainly based on the following shortcomings of the existing transfer strategies:

Financial Unsustainability poses an obvious risk to the long-term viability and purposefulness of technology transfer. Thus far, virtually all of the major organizations established with this aim, have depended on the donors' financial allocations and good will. After a certain time period the mechanism of functioning of many of these organizations has shifted towards securing the monetary support from the donors, on the expense of deviation from their true mission.

Restriction to Agro-biotech is another limitation of the present biotechnology transfer mechanisms. Up to date, the prime focus of S&T cooperation (North-South, South-South) in biotechnology has been agricultural research. The main target of them has been poverty alleviation via food security; by licensing the only most needed agro-biotechnologies.

Unprofitability of Transfer explains the restriction to agro-biotech, noted above. Most of the pharma-biotech inventions are protected by patents issued to private companies. Sharing of patented high

technology needs to be made feasible by profit-orientation. Dependency on inventors' / donors' good will cannot be perceived as a win-win collaboration. Competitive biotech research cannot be stimulated unless economic profit is sought. Trade relations need to be developed and included in this aspect, as well.

Directional and Regional Restriction of transfer is another characteristic of the available mechanisms. The collaboration so far has been mostly concentrated between the countries in the proximity of each other. Likewise, in many cases the transfer is unidirectional: towards developing countries, with North being the host of technology. This restricts the interaction in all possible directions and distances, competitive strategies for which need to be developed and fostered.

Public Sector-Orientedness remains to be central for most of the current biotechnology transfer discussions. Currently, there is dissatisfaction about low interest of the private industry in the research networks. Based on its leading position in biotech market as the holder of most intellectual property, private sector needs to be given a bigger role, and be encouraged into dialogue with public sector. Role of biotech SMEs need to be rediscovered.

In response to the current image of biotechnology transfer and these insufficiencies, with which 'genetic divide' is hindered from being addresses as it should be, the purpose of this thesis work is to develop the abstract concept of 'BioEntrepreneurial Partnership', identify its main dimensions and substantiate its theoretical validity / feasibility, without testing its empirical relevance.

6 - BIOENTREPRENEURIAL PARTNERSHIP

6.1 - Definition

BioEntrepreneurial Partnership (BEP) is a concept of Systems of Innovation (SI)-premised, profit-motivated biotechnology partnership, aiming to encourage biotechnology transfer and to address development.

6.2 - Institutional Innovation

Development is a concept, which so far has been strongly associated with the state and national developmental strategies. Modern science has come to advocate that, with increasing globalisation, development is becoming a universal issue. This is especially true for the future of development in a world where most states lack the capacity to influence their own economic development. Although globalization has provided new opportunities for those countries with the policy instruments and institutional and technical capacities to participate in increased international trade and investment, many others are being left behind and marginalized due to institutional insufficiency. In the face of these challenges, there is a real urgency for developing countries to work together closely with their developed counterparts to build their capacity for innovativeness and creativity. (UNCSTD, 1999)

According to Hettne (1996), in the face of converging transnational interests, there is an obvious trend towards an international system, or, international political economy (global system). For the biotechnology sector development in particular, there is an indispensable need for a 'global biotechnology governance regime' – to homogenize the international biotech standards, to overcome the growing dilemma of 'genetic divide' via facilitating biotechnology interaction (transfer) with developing countries, and to render them active in the new bioeconomy (Juma, 2001). Whether the adoption of agro- and pharma-biotechnology will contribute significantly to ensure food security, improve the environment and increase life expectancy depends on the existing social, political and economic conditions in developing countries. This activity emphasizes the design of global systems of innovation that accommodate the imperatives of biotechnology.

Introduction to SI as a theoretical framework for the idea of BEP is made in the chapter 3. The core of the SI approach consists of the discussion of 'institutions' and 'institutional innovation'. Edquist *et al* (1995) define institutions as "sets of common habits routines, established practices or rules, which regulate the

relations and interactions between individuals and groups. Organizations are formal structures with an explicit purpose that are consciously created; they are players or actors".

Alternatively, institutions can dually mean "things that pattern behavior" (Lundvall, 1992) like norms, rules, and laws; and the other "formal structures with an explicit purpose" (Nelson *et al*, 1993), or what is normally called organizations. Lundvall (1992) states that: "Institutions provide agents and collectives with guide-posts for action' and as such 'institutions may be routines, guiding everyday actions in production, distribution and consumption, but they may also be guide-post for change. In this context, we may regard technological trajectories and paradigms which focus the innovative activities of scientists, engineers, and technicians, as one special kind of institution."

Thus, institutions play various roles in shaping up innovative processes. R&D laboratories, patent systems and technical standards are often regarded to be 'institutions' intended to stimulate technical innovation. On the contrary, included in 'organizations' are firms, universities, state agencies etc. In the area of economic relations they have a crucial role in establishing expectations about the rights to use resources in economic activities and about the partitioning of the income streams resulting from economic activity (Runge, 1999). A modest sketch of institutional clusters affecting biotechnology field can be retrieved from European Competitiveness Report (2001). These basically include:

- Structure and funding of research system
- Industry-University relations
- Financial markets and venture capital
- Regulation of Intellectual Property Rights (IPR)
- Biotechnology policies

In order to perform their essential role, institutions must be stable for an extended period of time. However, institutions must change if development is to occur – they need to be innovated. Anticipation of latent gains to be realized by overcoming the disequilibria resulting from changes in factor endowments, product demand, and technical change is a powerful inducement to institutional innovation. Remarkably, the 'demand' and 'supply' dimensions of innovation stand also true for institutional change. (Ruttan, 2001)

In country-specific context, institutional discussions receive much attention and are viewed in National Innovation System (NIS) framework. As Freeman (1987) writes, NIS is "the network of institutions in the

public and private sector whose activities and interactions initiate, import, modify and diffuse new technologies". The NIS consists of various research institutions, firms, universities and other institutions. Andersen *et al* (1988) explain different types of institutions in the NIS:

1. National R&D institutions which, being spin-offs of universities and public sector, are funded principally by government, other public funds and in some cases non-profit organizations;

2. Institutions which are linked to firms;

3. Educational and training institutions which supply scientists, technicians and engineers possessing appropriate skills;

4. Policy making institutions which monitor the implementation of R&D in the public sector and ensure the necessary degree of coordination with private sector R&D.

Whilst it is abundantly clear that different policy responses are required in different countries and regions (as due to the unique NIS strategies), there are common key points that all need to consider. According to the Innovation Directorate of European Commission (2003), these primary objectives for fostering innovation should concentrate around:

- Improving coherence in innovative policies
- Developing regulatory framework conducive to innovation
- Encouraging creation and growth of new innovative firms
- Improving key interfaces in the innovation system

Successful innovation systems are judged to be those where productive relationships have developed between research and non-research organisations and between public and private organisations. There is no institutional blueprint for an ideal innovation system. Rather, principles of SI thinking can be used to guide institutional change, and the ways of achieving should be devised in accordance with local contexts. Vitally, considering both national biotechnology innovation strategies and the needs of the global bioeconomy, steps need to be taken in their intersection. In other words, the 'demands' for biotechnology innovation – the 'genetic divide' and need for global biotechnology governance regime – need to be addressed in the intersecting context of national and international interests. Hence, the 'supply' will be the

necessary institutional changes, which will be able to feedback to each element of the CLD. It is the true aim of the BEP idea to encourage these changes.

Innovation in biotechnology depends heavily upon complex integration of basic research and market-induced applied R&D. This takes place largely *between* firms and research institutions, rather that *within* firms. The following figure depicts the conceptual framework of national institutional context for biotechnology, linking national and firm-level features. (Bartholomew, 1997)

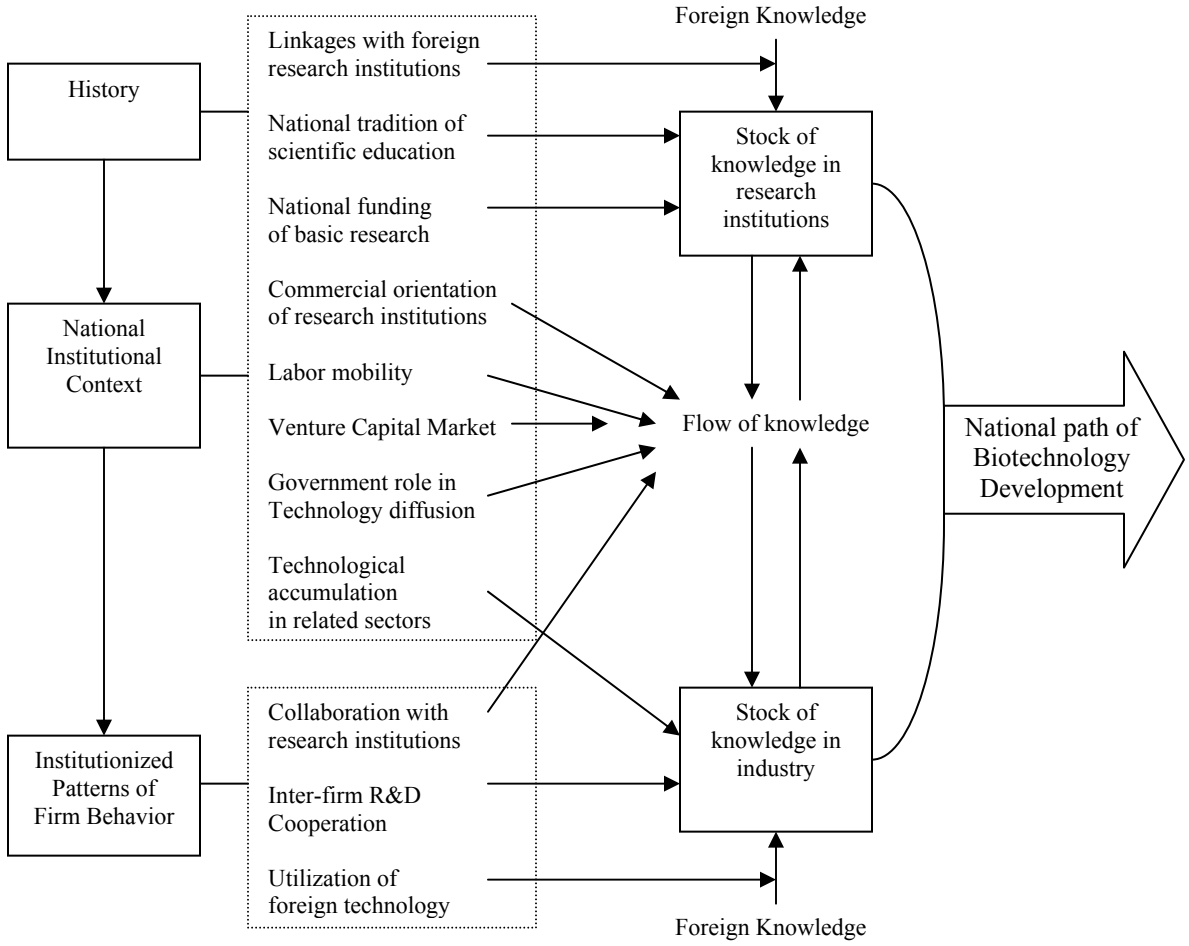

Figure 6.1: Scheme of National Biotechnology Innovation Systems. Adopted from Bartholomew, 1997.

From the figure it is evident that the three main components of institutional features are those affecting 1). Stock of knowledge in research institutions; 2). Flow of knowledge between research institutions and industry; and 3). Stock of knowledge in industry. Pointing at the three main characteristics of the growing bioeconomy (chapter 5), and since this thesis deals with the commercial aspects of technology generation and diffusion, I have concluded three main factors for scrutiny in the forth-coming chapters:

1. Public-Private Sector Dialogue in Biotechnology
2. Reinforcement of Biotechnology R&D Networks
3. Biotech Start-ups and Availability of Venture Capital

National patterns of biotechnology R&D are shaped by the configuration of country-specific institutional features into a system of innovation, which supports the accumulation and diffusion of knowledge between the scientific and industrial communities. The variation across these different national innovation systems provides a compelling motivation for international technological cooperation; it also 1) Leverages cross-border differences in regulatory framework; 2) Accesses leading-edge scientific research; and 3) Seeks means to finance expensive R&D programs. (Bartholomew, 1997) All this serves to complement the gaps within the national innovation systems of the partners, thus, fostering institutional harmony. BEP is a means for achieving this.

6.2.A - Private – Public Sectors Dialogue

Dialogue between private and public sectors stands central to the notion of modern institutional innovation. It is believed that such partnerships will effectively combine the resources of the private sector, namely, market orientation, access to finance, business experience, technical expertise and entrepreneurship with the resources and inputs of the public sector, namely, public accountability, legal framework, regulations, social responsibility and an enabling environment. (Dowrick, 1995) In biotechnology *per se*, as I have shown in former chapters, the leading innovative role is in private hands. This fact indirectly grounds the need to provide every feasible incentive for the biotech private sector to bring it into dialogue arena and to facilitate technology transfer.

The new growth theories and models emphasize the important effects of public policy directed towards innovation, getting the right volume and mix of innovative activity involves much of the traditional tool-bag of microeconomic analysis focusing on non-rivalry, risk and incentive structures. “The dominant line of economic analysis stresses that new ideas are essentially public goods: whether they concern new ways to make existing goods, or whether they pertain to previously unconceived products and services, it is not only easy but also socially efficient for imitators to benefit at little cost from the efforts of the original innovator. On the other hand, new ideas and products do not typically arrive effortlessly; they are usually the product of sustained effort and resources channeled into research and development.” – according to Dowrick (1995).

Given the public good nature of ideas, the principal problem perceived by economic analysis is that of reconciling simultaneously the need to provide innovators with incentives and the desirability of making the new ideas available at marginal cost to potential users. There are several different approaches to the problem of how to reward the innovator in order to motivate sufficient innovative activity. Analysis of the incentive problem tends to focus around the two poles of public subsidy and private property rights, whilst public policy in most industrialized economies consists of varying mixes of these two approaches. The problems of private innovators are the essential riskiness of innovation and how to appropriate the benefits arising out of their efforts. The inherent uncertainties and time-scale involved in the production and marketing of innovation leads to the conclusion that direct public subsidy is very unlikely to be correctly targeted; rather, they argue in favor of strengthening and lengthening patent protection on genuinely new inventions. (Dowrick, 1995)

The traditional research paradigm represents discoveries flowing linearly from basic science conducted in public institutions to applied research and commercialization undertaken largely by private industry. In contemporary biotechnology, the sharp line between private and public research activities fades away, as their interests become to overlap at some points. (Rausser, 1999) He argues that research universities' basic science stretches over a very long run planning horizon, and that planning horizons of private companies have become more aligned with those of research universities, as they have moved into long term R&D in the field of life science. Hence, at some stage in the R&D process, research universities turn to private companies that have greater expertise in the commercial aspects of biotechnology.

Thus, accomplishing technology transfer is one of the most powerful reasons for a bridge to private industry. If it were not for public-private research partnerships, it is unclear when or even if critical technologies such as lasers, protease inhibitors, and bioengineering would have made their way into the marketplace.

6.2.B - R&D Networks And Corporate Partnerships

One of the most significant developments in the structure of the global biotechnology industry is networks involving partnering activities. They include joint ventures, strategic alliances, R&D partnerships, and consortia involving technology transfers, licensing agreements, management service and franchising agreements, cross-manufacturing and outsourcing agreements, etc. While NIS literature posits innovation connected to networks (Lundvall, 1992), such partnerships play a key role in the development of technological capabilities in the firms and institutions in partnering developing countries. (EAMS,

2002) As Zuscovitch *et al* (1995) define: "Networks represent a mechanism for innovation diffusion through collaboration and the interactive relationship becomes not only a coordination device to create resources, but an essential enabling factor of technical progress".

The *theory of the firm* (Holmström *et al*, 1988) has been challenging new economists to seek novel solutions in the innovation networks. As it proposes, there exist two approaches used for the explanation of why firms should cooperate: *Incentive-based & Knowledge-based*. The incentive-based approach focuses on cost-based and rational decisions and excludes crucial aspects of firms' strategies, which are influenced by a couple of factors lying by their very nature beyond the scope of these approaches. Knowledge-based approach is supposing quite different functions of innovation networks compared to the incentive-based approaches. Whereas the latter claims for a cooperation of innovation processes in networks due to cost-considerations, the former emphasizes knowledge creating attributes of innovation networks.

The increasing complexity, costs and risks involved in innovation enhance the value of networking and collaboration to reduce moral hazard and transaction costs. This provides an incentive to find new forms of technology cooperation involving two-way relationships, and attempts to share technological knowledge and collaborate on R&D, training, manufacturing, information management and marketing. Such technology partnerships are knowledge links that give firms access to other organizations' skills and capabilities. With respect to the different functions, it is revealing to ask for the motives to share cooperative agreements in R&D. Hagedoorn *et al* (1989) list the motives of firms participating in innovation networks:

1. Extremely high cost and risk of R&D in high tech industries;
2. Quick pre-emption strategies on a world scale which are preferable despite 'loss' of potential monopoly profit;
3. Shortening of period between discovery and market introduction;
4. Exploration of new markets and new market niches;
5. Technology transfer and technology complementarity; and
6. Monitoring the evolution of technologies and opportunities.

In connection to this, Hagedoorn *et al* (1990) say: "We have seen that only a relatively small number of motives matter for cooperation in these core technologies (biotech, IT, new materials). Motives have a different bearing for different modes of cooperation, but in general the search for new markets and entry,

the reduction of the period innovation, the technology complementarity of partners and monitoring technological opportunities are the major motives we have come across."

The growing need for these networks has led to a systemic approach for the policy analysis in innovation. There is urgency for a concerted movement in biotechnology, as due to the growing 'genetic divide'. Now that there exist a series of profitable corporate motives, BEP encourages developing partnerships both for individual corporate growth and for national biotechnology development interests, within the framework of necessary national innovation systems. In the light of the call for new entrepreneurial action pioneered by Schumpeter and continued by modern evolutionary economists, entrepreneurs both from developed and developing countries need to value this as an 'entrepreneurial opportunity' (Venkataraman *et al*, 2002) to bridge this technology gap.

6.2.C - Biotech Start-Ups And Venture Capital

The *economic theory of technological change* focuses on the firm as the primary research unit and examines the microeconomic incentives and impacts of private research for commercialization. Innovation allows firms to generate new and improved products, capital savings and, in the case of industrial processes, it brings cost reductions or quality improvements. This explains why firms are the main actors of the process of technological innovation. Their capacity to innovate is partly determined by their capabilities, partly by their capacity to adapt and apply knowledge produced elsewhere. (Feneuille, 1997) Recent studies of impact of innovative activity at the firm level on the larger economy, with focus on 'endogenously' generated innovation on macroeconomic growth, trade and industrial location assumed that innovation is a discrete event that occurs within firms (Romer, 1990; Krugman, 1998).

Historically, SMEs have played an important role in the process of industrialization in market economies. They are highly potential in terms of stimulating economic growth in the developing countries, providing significant employment with relatively low investment requirements and high utilization of local raw materials. The experience of some Asian countries shows that SMEs create more jobs per unit of capital invested than larger enterprises, and that they can contribute notably to improving the livelihood in both urban and rural areas, and are one of the powerful aspects of successful industrialization. (John *et al*, 2000)

Small firms hold a bigger percentage of patents than large firms, which are less productive in R&D. As Shane *et al* (1994) allege: "There are opportunities for cooperation between small start-ups and large

established firms in order to exploit technological spillovers and technological resources for product commercialization; resources of larger firms support innovation in affiliated smaller firms. Established firms form cooperative agreements with start-ups to learn biotechnology techniques and lessen the threat they pose as a substitute for traditional product development. These relationships benefit start-ups, which typically lack financial, marketing and distribution resources that established firms provide."

Another and a very important dimension of BEP is to increase number of biotech start-up companies and make VC available via corporate partnerships. Based on the fact that it is the start-ups, which serve as the knowledge generating units in biotech labor division, and which later transform into various types of functioning biotech companies, as they substantiate their scientific and financial base, their importance needs to be perceived as the seeds of commercial biotechnology. Since BEP aims at sustainable corporate relations and health, in its core lies profitable cooperation in terms of instruments that stand vital for long-term functionality, growth and viability of a biotech company. Modern survey reveals the important properties of biotech companies according to the stages of their development (Table 6.1).

	Early Stage ►	**Middle Stage ►**	**Late Stage**
Product Development	Conceptual	Trials under way	Commercial
Cash Flow	Negative	Negative - neutral	Positive - profitable
Capital Requirement	High	Varied	Varied
Corporate Structure	Generally require specialist advice	Developing	Established
Focus of Management	Protecting IP, developing for commercialization and funding	Funding + positioning for growth	Consolidation

Table 6.1: Biotech company development stages. Source: Misrack *et al,* 2000.

Several studies have documented the extraordinary resource demand of start-up companies in their growth process, which necessitates the cooperation with external partners, such as the VC investors. Obviously, regardless of the product development concept of a company, the main impediment of start-ups (depicted as 'Early Stage' in the table) remains in financial issues, as due to negative cash flow and high capital requirement before they turn capable of utilizing the products of their own R&D. Start-ups in the biotech-leader countries circumvent the issue via accessing abundantly available VC or engaging in strategic partnerships. (Welpe, 2002)

In Welpe's (2002) model, VC companies invest equity in promising young companies, based on their demands. Further cooperation between VC companies and start-ups is provision of non-financial services, such as management assistance, coaching and monitoring, which are intended to compensate for gaps in the entrepreneurs' experience, knowledge and resources. The same model, which is based on the assumptions of the *resource-based theory of the firm* and the *knowledge-based view*, shows that young companies have great technological expertise but often lack relevant knowledge in markets, management and strategy. It compliments the argument with: "Therefore, the experience of the lead investor is necessary for the provision of external, complementary resources and the transfer of relevant knowledge between VC and start-up and thus for the success and demand fulfillment of the portfolio company. However, the degree to which the interaction and cooperation with the VCs fulfills start-up demand, equals the success of the cooperation, and that it depends on both the lead investor's potential for cooperation and the relationship between lead investor and start-up."

Against this background, start-ups in the biotechnologically weak countries face the serious problem of surviving the embryonic stage of enterprise development because of inaccessibility to the discussed options (Bustamante *et al*, 2002). In this vein, BEP encourages that partnership strategies be arranged with early- and middle-stage biotech companies in developing countries – to give them lifeblood for stimulation of their own biotechnologies without shifting the loci of production. Likewise, providing favorable grounds to increase number of R&D biotech start-ups, and get them involved in vertical and horizontal partnerships is an issue to be considered in the framework of national biotechnology innovation systems.

7 - ANALYSIS

The three prime components of BEP are connected within the framework of institutional innovation, which is the foundation of SI. In the collective force of its components, BEP addresses 'genetic divide' by means of stimulation of the necessary institutional change and harmonization of its practices across nations. (Figure 7.1) It is not to mean that BEP stimulates the change from zero. Rather, the necessary institutional conditions favoring BEP need to be previously available and laid down by government initiatives. It is at his point that BEP may come into play and compliment the already initiated process of evolution, however, at a much faster pace. Though the connection between the three components in the figure below is clear from previous chapters, it is worth to remind that Public-Private (PP) Sector Dialogue plays the central role of all of them, because it is their interaction that brings out the necessary initiatives and lays the grounds for the other two components.

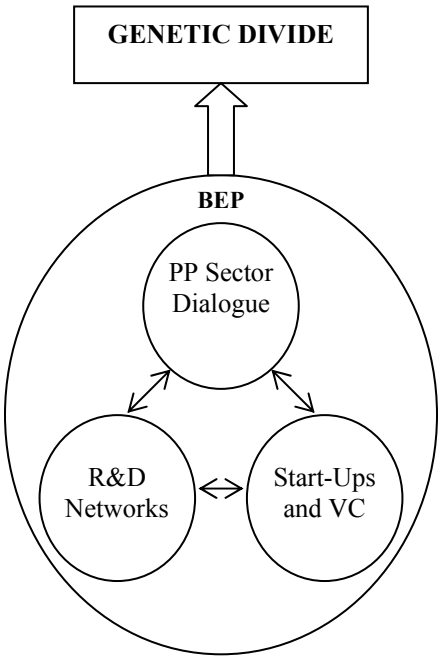

Figure 7.1: Schema of BEP, its components and effect on 'Genetic Divide'.

Juma's dilemma of 'genetic divide', around which builds the argument of BEP, is a phenomenon of insufficiency of institutional infrastructure for biotechnologies in developing countries. All its four factors shown in the CLD stem out of a common character: lack of harmony and mutual trust around fields of generation and diffusion of biotechnological knowledge and products – issues to be addressed by

institutional backup. For short reminder, the factors of Juma's dilemma and their concerns are given below:

Regulatory Capacity: relates primarily to facilitation of adoption of new biotechnologies, and secondarily to homogenization of regulations for trade of genetically modified organisms.

Market access: includes reduction of high tariffs/standards, facilitation of market entry for products of developing countries.

Flexibility of IP rights: concerns increased access of developing countries to patented commercial biotechnologies, and establishment of minimum requirements for IP protection, increase of trust and creation of incentives for inventive activities.

Management of risks and benefits: comprises alleviation of risk / reduction of uncertainty of enterprise building and development of new biotechnology products. Likewise, concerns reduction of risk dealing with environmental and health issues (stronger biosafety).

National systems of innovation in the various regions of the world and the way they affect the direction and pace of technological innovation and transfer is a critical component in defining policies and reshaping institutional infrastructure. More recently, technological learning has provided the policy basis for rapid industrialization among developing countries which have favored policies and laws that promote the local working of patents, parallel imports, compulsory licensing and exclusion from patentability for certain classes of technologies. Many of those are affected by the *evolutionary view.* Solleiro (undated) proposes a basic model for the *evolution* of policies to foster technological innovation and entrepreneurship in developed countries in two phases: starting and mature. Each phase is assigned specific objectives and goals, a specific set of obstacles, market failure and policy restrictions to deal with, and a policy framework.

The objective of the starting phase (Table 7.1) is to assure a collective, cumulative and multidisciplinary learning process on innovation setting the base for the assimilation of the R&D process in the economy. Though the model is broad and encompasses regulatory system formation in a variety of technology sectors, a general trend is clear when moving from the set objectives to the policy framework through the obstacles: unison of R&D, commercial tools, partnership models (inter-firm etc.) and domination of private sector.

Objectives and goals	Obstacles, market failures and policy restrictions	Policy framework and components
Generalizing R&D in domestic firms	Lack of good R&D projects	Learning process: government agencies promote links and certain typology of projects, and codify experiences from different policies. Programs for specific firms (SMEs) and sectors.
Cumulative process of collective and multidisciplinary learning	General market failures	Solid and flexible support
To reach a critical mass of projects	Lack of R&D activities in firms	Combination of economic and financial incentives with policies for institutional and market development Reduction of bureaucratic procedures Granting of innovation awards
Capacity building for policy definition and implementation	Little development of markets of consultancy in R&D and technical advice	Increase international collaboration Training in policy development
Definition of specific incentives for R&D in private sector	Inadequate institutional framework	Pro-active policies to promote projects including tax incentives Definition of both horizontal and specific support mechanisms

Table 7.1: Technology policies cycle: the starting phase. Adopted from Solleiro (undated).

Phase 1 begins based on already built public-private sectors dialogue and available knowledge and human resource. In the first step, the need is felt for generalizing R&D in domestic firms, the policy consideration for which is sought in putting emphasis on special programs for firms. In terms of BEP, this is realization of importance of SMEs and innovative start-up companies. In the second step, seeking to accentuate multidisciplinary learning and accumulate critical mass of R&D, various routes are formulated. Beginning with release of solid and flexible support, the prime of these routes are combination of economic and financial incentives with policies for institutional and market development, and granting of innovation awards. This is firstly as to identify and harmonize the obstacles for market access (tariffs, standards etc), and secondly to regulate protection for IP and to set minimal criteria for its utilization. In a further step of the starting phase, the goal is capacity building for policy definition and implementation. To achieve this end, increased international collaboration and training in policy development are necessary to make use of experiences of industrialized countries; this is the key to the institutional harmony.

According to chapter 5, the institutionalization of biotechnology innovation has been linked to a number of reforms, especially, international trade, intellectual property and biosafety laws. Biosafety and issues of trade with GMOs become addressed bye means of bringing and enacting regulations best recognized by international community. Similarly, the shift towards greater enforcement of intellectual property rights and compliance to the TRIPs agreement should be accompanied by measures that enhance the participation of the developing countries in international trade. These measures include a broadening of the intellectual property regime to cover products and resources that are provided by these countries. The TRIPs agreement represented an important step in efforts to harmonize intellectual property rules by establishing minimum standards against which countries could model national laws. The debate on the relationship between intellectual property and international trade is a continuation of divergent interests of developed and developing countries in regard to access to technology. The normative approach of TRIPs seeks to create a balance between intellectual property protection on the one hand, and the need to protect the public interest and reduce abuse of the other, providing developing countries flexibility to pursue their economic and social goals. (Juma, 1999)

As consolidation of innovative activities in the private sector continues, more incentives are granted in the form of reduction of tax barriers and other forms of horizontal and specific support. All this prepares the necessary background for the more sophisticated next phase. The objective of the mature phase (Table 7.2) is to restructure policies to favor more valuable and viable entrepreneurial projects. The growing number of innovative SMEs begins to exert pressure on the government for more favorable policies and more support of any kind, which is getting scarcer. Mechanisms for partnership promotion via engaging in alliances and building up R&D networks etc. become to be addressed at this stage. Furthermore, best policy practices begin to be applied, and innovative financial mechanisms in the form of VC become increasingly available for viable and sophisticated R&D projects. Selectivity increases as the selection process of evolution chooses out only promising R&D projects, eliminating the others. Thus, increased R&D complexity requires more well-trained and specialized personnel. As capacity building and international cooperation gets its way at a more advanced level, support to new categories of technological enterprises increases and evolution of biotechnology sector hones its excellences.

Objectives and goals	Obstacles, market failures and policy restrictions	Policy framework and components
Policy reformulation	Budget limitations Political limitations (v.g. large companies political influence)	Leveraging resources Partnership promotion Innovative financial mechanisms (venture capital) Best policy practices
Reduction of support for routine projects	Lack of capacity to identify relevant market failures and appropriate categories for R&D projects	Increased selectivity Specific incentives
Fostering transition to more complex R&D projects	Lack of personnel for R&D	Capacity building International cooperation
Support to new categories of technological enterprises	High transition costs Market failures and technical restrictions	New categories of projects Private sector as integrator of sectoral innovation clusters

Table 7.2: Technology policies cycle: the mature phase. Adopted from Solleiro (undated).

This analysis sums up that BEP can be a package of the main factors / initiatives involved in formulation of innovation policy in the field of biotechnology in developing countries. Its components cannot be considered aside the other factors that compliment evolution of a national innovation body. The tools on which BEP positions encourage friendship of public and private sectors, greater international technology collaboration, and are valuable in terms of transfer of biotechnology to developing countries based on profitable / commercial grounds, simultaneously rendering them active in the new and growing bioeconomy and addressing 'genetic divide'.

7A - EXAMPLE OF EVOLUTION OF INDIAN BIOTECHNOLOGY

Evolution of Indian biotechnology is one of the most vivid and ongoing evolutionary processes of nowadays, which transformed an ordinary developing country into one of the decisive players in world biotechnology today. This mini case study is to exemplify the aforementioned key points in evolution of biotechnology sector, though not in exact sequence, and to give credit to BEP thinking without seeking a direct empirical relevance of it.

7.A.1 - History and Infrastructure Development in India

Indian universities have been involved in the basic and applied research since the beginning of 20-th century, but more intensively since 1960s. Since independence, a concerted effort for scientific advancement in Indian laboratories has led to the creation of a large resource of trained scientific personnel. (Mukherjee, 1997)

India is among the first developing countries to recognize the importance of biotechnology as a tool to advance growth of agricultural and health sectors. The first official policy document was India's Sixth Five Year Plan of 1980-85, which addressed the need for biotechnology development in the country by calling for action in certain fields of biosciences and coordination on inter-institutional level and full utilization of available facilities and infrastructures. The National Biotechnology Board was established in 1982 as an official agency dedicated to biotechnology development. In 1986 an actual government body called the Department of Biotechnology, under the Ministry of Science and Technology, replaced it. (Maria, 2003)

Since 1986, investments have been made towards capacity building, both in terms of human resource and sophisticated R&D infrastructure by the Government of India. (Rao, undated) The National Biotechnology Board had launched an integrated training program in 1984, to cope up with growing demand for highly trained manpower. Under supervision of the Major Government, this was initiated by means of establishing undergraduate and graduate-level biotechnology programs at various Indian universities. (Chaturverdi, 2002) It also provides grants to the University Grants Commission, which is responsible for the coordination, determination and maintenance of their standards and release, for motivation of R&D projects. (Maria, 2003)

7.A.2 - Public Initiatives

Public initiatives in India began working in the interface of the public-private dialogue. Innovative biotechnology firms began to appear, and as their numbers rose, so did their demands from the government. According to the first major analysis on risk capital for India, reported in 1983, new Indian biotech companies often confronted serious barriers in terms of equity capital, which undermined their future prospects of expansion and diversification. Also, it pinpointed the need to revive the equity mechanism by ensuring competitive return on investment, uncovering the institutional insufficiency with respect to the evolution of VC. The role of VC was recognized initially by the following institutions:

Industrial Development Bank of India, Industrial credit and investment corporation of India, State Finance Corporations and Small Industries Development Bank of India. (Bowonder, 2004)

This was the first phase of the growth of VC in India when the concept of VC received official recognition in 1988 with the announcement of the VC guidelines. Subsequently, Government of India formularized the procedures that can be used for starting venture funding, after which technology-oriented innovative businesses started by first generation entrepreneurs received support. The second phase of VC growth attracted many foreign institutional investors. Overseas and private domestic venture capitalists began investing in VC funding, which were later driven by 1996 regulations. (Bowonder, 2004) In 1992 Technology Development Board was established by Ministry of S&T to provide financial assistance to industrial concerns and other agencies attempting development and commercialization of indigenous technology or adopting imported technology for wider domestic application. New start-up companies especially benefited from this assistance. (Rao, undated)

Evolution also continued at the state level when several state governments in India have launched different initiatives to attract biotechnology industry to their respective states - Andra-Pradesh is one of them. As a part of its state biotechnology policy, companies would benefit from lower sales tax on all biotechnology products produced within the state. By means of cumulating the existing state strengths, the policy aimed at rapid commercialization of biotechnology on the state level. Several other states were interested in the concept of developing biotechnology parks. (Chaturverdi, 2002)

As the network grew, India felt the need to join up its biotechnology units. Biotech Consortium India Ltd was set up in 1990 as a public company, with the objective of providing the linkages among research institutions, industry, government and funding institutions, to facilitate accelerated commercialization of biotechnology.

To extend its international cooperation, India has signed several bilateral agreements for implementing joint projects and human resource development programs. There are now several ongoing activities with both developed and developing countries, such as Germany, UK, Switzerland, Sweden, Japan, France, Israel, Sri Lanka, Myanmar etc. The earliest, however, has been the Indo-US collaboration known as Vaccine Action Program focused on developing vaccines and diagnostics for communicable diseases, followed by the Indo-USSR program on assisting manufacture of Oral Polio Vaccine. The main objective of the biotechnology international collaboration according to Rao, (undated), "…is to assist in implementation of national programs; acquisition of knowledge in areas of specialization not available

within the country; share expertise and large scale facilities; participation in joint R&D programs; and add to the economic well-being of the country through private sector participation in product and process development, technology transfer and communication." (Rao, undated)

From another perspective, the US-India Biotechnology Alliance is aimed at facilitating exchange of information on bilateral trade, investment opportunities and business cooperation. It will facilitate bringing together private industry and research associations of both countries, and thus ensure bio-partnership. The alliance intends also to facilitate commercial joint ventures, collaborative research, public-private partnerships, technology trade licensing and distribution agreements – tools that can increase institutional homogeneity. (Feller, 2003)

7.A.3 - Regulations

Increasing international collaboration brought out the need for implementation of best policy practices and homogenization of regulations, particularly around the fields of biosafety and IPRs. India's first Biosafety and Recombinant DNA Guidelines of 1990 fall under the Environment Protection Act of 1986. After India signed the Convention on Biodiversity in 1994, these guidelines were revised by the Department of Biotechnology to accommodate the safe handling of GMOs in research, application and technology transfer. They address large-scale production and release of GM plants, animals and products into the environment. At least 165 institutions are controlled by specially gathered committees for conformity to the guidelines. One of them is Institutional Biosafety Committee. (Chaturverdi, 2002)

Indian IP regime enacted in 1970 differed from the Paris Convention standards in: patent protection, period of protection, and importation of patented products. It was prepared to facilitate technology transfer for industrial development and provide incentive for inventive activities. As a consequence of the differences, India was not part of the Paris convention until 1995 when it joined WTO and had to sign TRIPs agreement, which requires conforming to the most recent version of the Paris Convention for the Protection of Industrial Property. India has now to harmonize its domestic laws and institutions with the WTO standards before 2005. (Maria, 2003)

Based on these grounds, technology transfer was accelerated with establishment of Biotechnology Consortium India Limited in 1990, to foster effective linkages between academic, financial and industrial institutions, and the policy-making authorities. Regarding this, Maria (2003) is able to write: "So far, more than 60 technologies and research leads from the Government funded R&D projects have been

transferred to Indian industries for scale up, validation and commercialization. With a view to encourage the institutions to file patent applications on their innovations, and to motivate them to transfer their technologies for commercialization, and facilitate them to reward their inventors, some more instructions were issued during 2002 for institutions receiving funds for research projects from the Ministry of Science and Technology."

7.A.4 - Today's Picture and the Future of Evolution

Today, it looks like India has left 'Genetic Divide' in the past and successfully keeps the line with world biotechnology. There are total 176 biotechnology based companies in India. Shown in Figure 7.2.A, as many as %49 these are agriculture-based, almost %25 are active in health-related and medical activities, while %26 have varied interest including environmental biotechnology. Although in terms of numbers health biotechnology companies are lesser than those active in the agriculture sectors, they account for a much higher proportion of foreign alliances (Figure 7.2.B), as their external orientation continues to grow. (Chaturverdi, 2002)

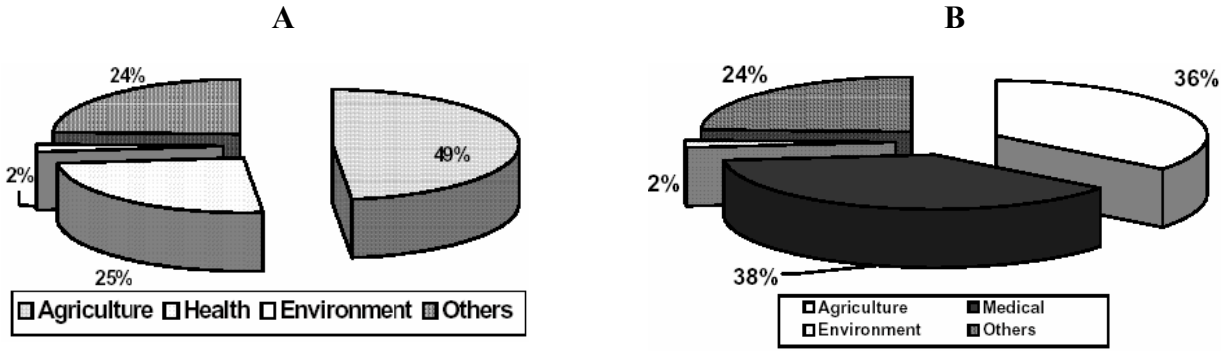

Figure 7.2: A – Sectoral breakup of biotechnology firms in India
B – Foreign alliances of Indian biotechnology firms (Source: Chaturverdi, 2002)

It is estimated that the size of Indian biotechnology market ranges between USD 1.5 to USD 2.5 bn. Of this, the agriculture sector market is valued between USD 450 to USD 500 mn and diagnostic/vaccines market at USD 150 to USD 420 mn. Overall, the size of the industry is estimated to have grown to USD 1.5 to USD 2.5 bn between 1999 and 2002. By 2010 it could reach USD 4,3 bn. (Chaturverdi, 2002)

The key markets for the Indian biotechnology firms include research and production of industrial materials, vaccines, diagnostics, veterinary products, and agro-biotech products. The most advanced biotech developments, which are bioinformatics and genetics, are a key focus of the major companies. It

is estimated that more than 15.000 scientists are currently employed in the biotech sector, twice the 2001 total. (Feller, 2003)

India's have already succeeded to a certain extent to homogenize its biotech institutions and regulations, and make them compatible to the world standards. However, to stabilize its respected position, India has sought further evolution in issues, which Maria (2003) describes as follows:

"- *Clear IPR protection scenarios*: IPR regime that will emerge from the convergence with the WTO standards.

- *Coordination of efforts between central and state governments*: to make states attractive location for biotechnology-based industries. This will focus on international competition for attracting such activities rather than on an inter-state competition.

- *Radical tax and duties exemption enhancing the competitiveness of India-based private research*: to make India attractive in terms of biotech research activities. A fast and easy process of certification of research units should be set up.

- *Creation of a single representation association*: to create a single representative association independent from political sphere. This association will gather the biotech companies as well as the public research centers willing to market their technology.

- *Focused strategies*: to support the different business models emerging from the diffusion of biotechnology in India."

8 – DISCUSSIONS AND CONCLUSIONS

Promise of biotechnology for Sustainable Development is still debatable. On one hand, for example, we have arguments about the questionable environmental and health hazards of GMOs. On the other hand, we have irrefutably useful miracles of this technology, such as those presented in the Chapter 2. *Any* potential technology can be dangerous if abused; such as nuclear technology which can be used to produce destructive bombs and very cheap electric energy. In this vein, biotechnology, when practiced correctly, can indeed be regarded as a sustainable technology. Various applications of chemical and environmental biotechnology, such as for cleaner ways of industrial production and utilization of renewable resources suggest its potential for environmental compatibility. Modern medical biotechnology, however, offers better healthcare for the world's aging population and impoverished, and innovative treatments for previously non- or ill-cured diseases. Agricultural biotech, likewise, increases nutritional value of foods and makes them resistant to devastating diseases. These features show its social responsibility. Moreover, increasing economic profit and new employment opportunities brought by the growing biotechnology sector point at its economic viability.

Today, biotechnology is practiced to a satisfactory extent only in several developed countries with leadership of US, Europe and Japan, controlling its main markets in pharmaceutical, agricultural and environmental fields. Thus, the confluence of these new biotechnologies and market niches they occupy forms the new 'bioeconomy', which is mainly driven by the private sector, and characterized by the emergence of new institutional structures and novel technology cooperation strategies.

Bioentrepreneurship, the business of biotechnology, is central to the formation of bioeconomy, as it is one of the main incentives for practice of today's commercial biotechnology. Due mainly to institutional insufficiency, developing countries have been out of the circle of the new bioeconomy. This technology gap between developed and developing countries is known as 'genetic divide'. Current biotechnology transfer strategies are failing to address the issue, and novel win-win partnership approaches are needed.

BEP stands as a promising solution. The concept is SI-premised and simultaneously aims at biotechnology transfer based on commercial motives, and closure of the growing biotech gap. However, reshaping their National Biotechnology Innovation Systems in the context of Institutional Innovation is indispensable for developing countries to play this scenario. Of special focus for them is to recognize importance of, and incorporate into their national biotechnology development paths the following criteria:

1 – Public-Private sectors dialogue in biotechnology,
2 – Reinforcement of biotechnology R&D networks, and
3 – Biotech start-ups and availability of funding i.e. VC.

Based on the already laid favorable institutional grounds, BEP is deemed to address 'genetic divide' via stimulation of the necessary further institutional change and harmonization of its practices across nations. Thus, the process of 'evolution' of the biotechnology sector will continue at a much faster pace, as illustrated by the Indian biotechnology.

Personal correspondence with Victor Konde, professor at Belfer Center for Science and International Affairs, Harvard University, revealed several questions as to what to account this business-based and entrepreneurial approach, and if the private-private partnerships as such would pay off. To make an analogy, the so-called 'digital divide', the computer technology gap between developed and developing countries, was similarly bridged through entrepreneurship and building businesses in developing countries. For instance, entrepreneurial partnership endeavors of Metrocomia, a Danish Internet enterprise, with Ugandan companies gave fruitful results (Madié, 2001). While for technological entrepreneurship to foster regional transformation in developing countries, favorable legal systems, capital markets and other infrastructure facilities are the necessary *tangible* factors; it is crucial to primarily stimulate the *intangible* factors, such as innovative thinking and entrepreneurial spirit (Venkataraman, 2003). These reasons characterize BEP's combination of business and innovation approaches. Since biotechnology capabilities are mainly promoted in public institutions in developing countries, Konde's another concern was about how to link them to the private enterprises in the North. BEP will seek direct liaison exclusively with the private sector, rather than the public sector, though the dialogue between the two will be favored. The special profitable arrangements between the transferor and transferee sides, however, would not raise doubts about the riskiness of the investments.

Thus, BEP is a scenario for developing countries with some level of already built favorable biotech infrastructure, such as Korea, India, China, Brail etc. BEP can be a potentially central strategy to be sought in designing National Biotechnology Development Paths of many developing countries, which may want to join the new bioeconomy in the future. However, the entire idea needs to be narrowed down to a country specific basis to include the inherent features.

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