ECONOMICS OF BIOTECHNOLOGY

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DISSEMINATION PAPER - 35

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1. Introduction

Biotechnology includes a wide range of procedures for modifying living organisms for serving human purposes. The range of living organisms range from cells, cellular components to living organisms. Research, agriculture as well as industry are positively affected by biotechnology. The processes that "biotechnology" includes, in order to modify living organisms, ranges from domestication of animals, cultivation of the plants, and improvements to the same through breeding programs. These programs include artificial selection, hybridization, genetic engineering as well as cell and tissue culture technologies. According to the American Chemical Society biotechnology is “The application of biological organisms, systems, or processes by various industries to learning about the science of life and the improvement of the value of materials and organisms such as pharmaceuticals, crops, and livestock”. Biotechnology is dependent on knowledge and methods from outside the sphere of biology like bioinformatics, bio robotics, chemical engineering and bioprocess engineering.

Bioinformatics is an interdisciplinary field which addresses biological problems using computational techniques, and makes the rapid organization as well as analysis of biological data possible. Green biotechnology is biotechnology applied to agricultural processes. Red biotechnology is applied to medical processes. White biotechnology, also known as industrial biotechnology, is biotechnology applied to industrial processes. Blue biotechnology is a term that has been used to describe the marine and aquatic applications of biotechnology, but its use is relatively rare. The investment and economic output of all of these types of applied biotechnologies is termed as “bio economy” (Convention of Biological Diversity).

Biotechnology is used in four major industrial areas-health care (medical), crop production and agriculture, non-food (industrial) uses of crops and environmental uses.

2.Impacts of Biotechnology:

The biotechnology industry's economic contributions consist of direct, indirect and induced impacts. These are discussed below.

The *direct impact* of the biotechnology industry is the economic impact directly attributable to biotechnology firms – their employees, revenues and wages. In 1999, biotechnology firms directly employed about 150,800 workers and produced revenues of $20 billion In addition, they paid their employees and owners $15 billion in personal income (Global Biotechnology Report,2010).

Indirect and Induced Impacts: In addition to the direct impacts of the biotechnology listed above, the industry generated revenues, jobs, salaries and taxes through a number of indirect and induced impacts. Indirect impacts are the result of purchases made by the biotechnology industry from other industries. To operate, biotechnology companies create economic activity in non-biotechnology companies, such as computer and equipment manufacturers, and contract research organizations. The revenues of these industries that are generated by the activities of the biotechnology industry are called the indirect impact. The induced impact of the biotechnology industry is created by the purchases of workers and owners in the biotechnology and supporting industries. These employees and owners purchase goods and services in the general economy with the salaries and capital gains they earn. The revenues generated by these purchases are called the induced impact. The sum of the direct, indirect and induced impacts is the total economic impact of the biotechnology industry.

3.Applications of Biotechnology:

3.i. Agriculture:

Biotech crops or genetically modified crops are plants used in agriculture. The DNA of these plants has been modified with genetic engineering techniques. This is done in order to discover new characteristics of the same plant which does not occur naturally in the species.

This Gm crops are usually pest resistant, disease, chemical treatment resistant, can protect themselves in stressful environmental conditions. Farmers have widely adopted GM technology. Between 1996 and 2015, the total surface area of land cultivated with GM crops had increased by a factor of 94, from 17,000 square kilometres (4,200,000 acres) to 1,600,000 km^2 (395 million acres).

Biotech produces crops that have insect resistance, enhances crop herbicide tolerance and facilitates the use of more environmentally sustainable farming practices. Biotech in agriculture performs several functions like- Generates higher crop yields with fewer inputs, lowers volumes of agricultural chemicals required by crops-limiting the run-off of these products into the environment, biotech crops that need fewer applications of pesticides and that allow farmers to reduce tilling farmland, develops crops with enhanced nutrition profiles that solve vitamin and nutrient deficiencies, produces foods free of allergens and toxins such as mycotoxin and improves food and crop oil content to help improve cardiovascular health(Trajtenberg,1990)

3.ii. Biodiversity and DNA banking:

Generally, more plant conservationists are turning to DNA technologies to have effective conservation strategies. The DNA bank is an efficient, simple and long-term method used in conserving genetic resource for biodiversity. Compared to traditional seed or field gene banks, DNA banks lessen the risk of exposing genetic information in natural surroundings. It only requires small sample size for storage and keeps the stable nature of DNA in cold storage. Since whole plants cannot be obtained from DNA, the stored genetic material must be introduced through genetic techniques. Plant DNA banks have emerged as new resources with great potential for characterizing and utilizing biodiversity. Other botanical collections, genetic resource collections, herbaria, botanic gardens and seed banks are highly valued on the basis that they represent important national and international resources. Collections for biotechnology and biodiversity evaluation have traditionally been based on living plants managed in seed banks, field gene banks, botanic gardens or in situ reserves, or based on dried plants managed in herbarium collections. The plant taxonomy and systematic community has responded to the biodiversity crisis by defining three major challenges:

(1) Completing the inventory of life,

(2) Discovering evolutionary relationships through phylogenetic, and

(3) Providing information via the Internet.

DNA collections can help with all three of those activities. DNA sequence analysis is useful in the identification and delimitation of species and higher taxa and is also set to become increasingly important via DNA taxonomy and DNA bar-coding. Analysis of morphological, chemical and anatomical characteristics of herbarium specimens can be used for assessment of genetic variation within and between species, but none of these can claim to offer the same potential as DNA. After all, genomic DNA samples represent the entire genetic component of the target organism (Amini,et al,2014)

Biological diversity (biodiversity) is the variability among living organisms: within and between species and ecosystems. ... Biotechnology is presently used for the conservation, evaluation, and utilization of biodiversity particularly for important crops, species etc. Crop Diversity can be managed with crop rotations, intercropping, fallowing, agroforestry and different crop varieties which will restore the nutrients of the soil as well increase production. The benefits of crop diversity are illustrated below in fig1.

Crop Diversity – *Manage with crop rotations, intercropping, fallowing, leguminous crops, insectary strips, agroforestry; different crop varieties (e.g. multiple cultivars, native forages)*	
Benefits • Higher organic matter in surface soils increases abundance, diversity & activity of organisms responsible for nutrient cycling; can improve yield • Plants requiring less water reduce water consumption, costs for water & irrigation • New crops can provide a market advantage • Insectary strip crops support predatory & parasitic insects; host pollinators, reducing need for honeybee rentals	**Case Studies** • Strip-cutting alfalfa increased yields 15% and beneficial arthropods 400% per acre compared to full-cut alfalfa *(UC Davis, Entomology).* • In an extreme drought year, corn yields were 137% higher in a legume/manure-based organic system than in a conventional system *(Rodale Institute).* • Long-term crop rotations (3-4 yrs) have 200x less toxic runoff than short-term rotations (1-2 yrs) *(Iowa State University).*
Considerations • Intercropping may affect harvesting strategy • Limited by types of crops that can be grown in an area • Time commitment for additional planning & management	

Fig:1 Benefits of Biotechnology in Crop Diversity (Biodiversity Factsheet, 2013).

Biotechnology has greatly helped landscape diversity and species diversity. In one hand where landscape diversity enables to enrich the diversity at landscape level by studying various functions of different landscapes whereas when it comes to species level the study becomes more intricate as it forms new genome for both plants and animals. Each mutated genome serve varied uses from disease resistant to high yielding types. The below given fig 2 and fig 3 elaborately briefs us with the benefits of landscape and species diversity respectively.

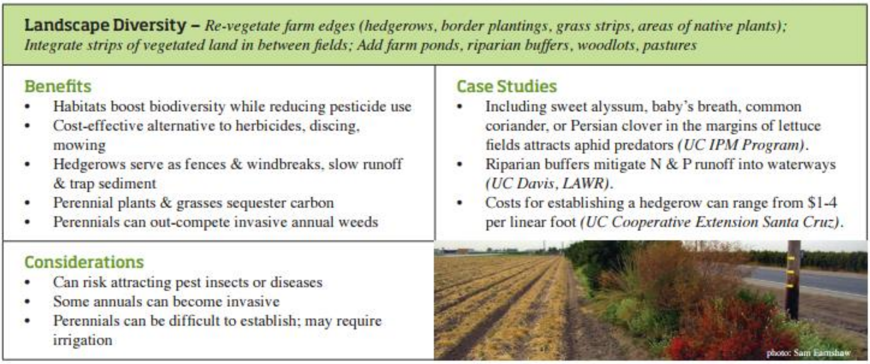

Fig:2 Benefits of Biotechnology in Landscape Diversity.

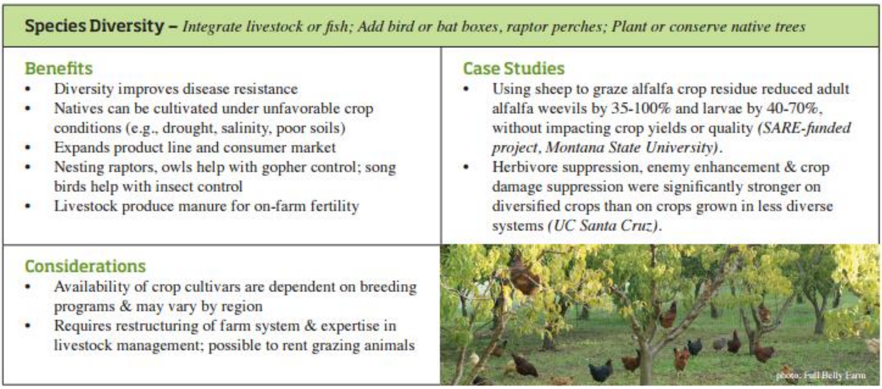

Fig 3: Benefits of Biotechnology in Species Diversity.

3.iii. Industry:

Industrial biotechnology employs the practice of using cells such as micro-organisms, or components of cells like enzymes, to generate industrially useful products in sectors such as chemicals, food and feed, detergents, paper and pulp, textiles and biofuels.

As per Biotechnology Innovation Organisation, Biotech uses biological processes such as fermentation and harnesses biocatalysts such as enzymes, yeast, and other microbes to become microscopic manufacturing plants. Biotech is helping to fuel the world by:

1) Streamlining the steps in chemical manufacturing processes by 80% or more;
2) Lowering the temperature for cleaning clothes and potentially saving $4.1 billion annually;
3) Improving manufacturing process efficiency to save 50% or more on operating costs;
4) Reducing use of and reliance on petrochemicals;
5) Using biofuels to cut greenhouse gas emissions by 52% or more;
6) Decreasing water usage and waste generation
7) Tapping into the full potential of traditional biomass waste products.

4. Bioremediation:

Bioremediation is a waste management technique that involves the use of organisms to remove or neutralize pollutants from a contaminated site. According to the EPA, bioremediation is a "treatment that uses naturally occurring organisms to break down hazardous substances into less toxic or nontoxic substances". Technologies can be generally classified as *in situ* or *ex situ*.

In situ bioremediation involves treating the contaminated material at the site, while *ex situ* involves the removal of the contaminated material to be treated elsewhere. Bioremediation may occur on its own (natural attenuation or intrinsic bioremediation) or may only effectively occur through the addition of fertilizers, oxygen, etc., that help encourage the growth of the pollution-eating microbes within the medium (bio stimulation). Microorganisms used to perform the function of bioremediation are known as bio remediators. However, not all contaminants are easily treated by bioremediation using microorganisms. For example, heavy metals such as Cd & Pb are not readily absorbed or captured by microorganisms. A recent experiment, however, suggests that fish bones have some success absorbing lead from contaminated soil. Bone char has been shown to bioremediate small amounts of Cd, Cu & Zn (Shah,2014). The assimilation of metals such as mercury into the food chain may worsen matters.The microorganisms may be indigenous to a contaminated area or they may be isolated from elsewhere and brought to the contaminated sites. Contaminant compounds are transformed by living organisms through reactions that take place as a part of their metabolic processes. Biodegradation of a compound is often a result of the actions of multiple organisms. A bioremediation can be effective only where environmental conditions permit microbial growth and activity, its application often involves the manipulation of environmental parameters to allow microbial growth and degradation to proceed at a faster rate.

5. International scenario of Biotechnology:

The US is first in the number of biotech firms, PCT patent applications, and biomedical treatment approvals, with Spain coming second, according to the OECD 2015 report on biotechnology statistics. According to the report, the U.S. has 11,367 biotech firms followed by 2,831 in Spain and 1,950 in France. They are followed by Korea, Germany, United Kingdom, Japan, Mexico, New Zealand and Belgium rounding out the top 10.

Small biotech firms are the rule rather than the exception, with 72 percent of the biotechnology firms in the United States having 50 or fewer employees.

The top countries in the world adapting biotechnology are: -

a) Malaysia ranks third in the world for the best Enterprise Support of its biotech industry by Scientific American’s Worldview Scorecard. Malaysia has strong scores for Enterprise Support and it is a biotech hub where industries thrive with access to a broad collection of business resources.

b) India: As a member of the BRIC countries, India has progressively expanded their biotech industry, boosted their bio-diversity, and improved governmental relations with private sector organizations. India is established as a hub for biotechnology.

c) Canada ranks third in the world for the best biotech hub outside the US. Canada has shown tremendous strength and innovation in the past decade to improve its industry. Canada has excelled in its education and workforce sectors, retaining a large number of professionals with doctorate degrees in the life sciences and Intellectual Property(IP) protection for innovative discoveries.

d) Italy has the second highest score in IP protection and has become one of the leading countries in the biotech industry. The patent protection policies implemented by the Italians ensure that a company's hard work will be safe from outside parties threatening to deny a return on research and development investments and thereby make Italy a favourable location for business.

e) Brazil has made progress in its biotech industry, obtaining a strong scientific basis with the aid of its academic institutions. It also has developed several plans to reduce bureaucratic restrictions to research and development and develop incentives for more collaboration between the academic and industrial sectors(OECD,2015)

6.Economics of Biotechnology:

More research is needed to develop biotech activity. Though health care premiums are growing rapidly and drug cost increases are getting a lot of press, it should be considered that the benefits of new drugs have historically outweighed their higher cost.

It is true that the policymakers should encourage basic and generic research. But policymakers should consider the fact that incentives are appropriate for markets to perform efficiently and price controls or forcing biotech firms to give up property rights could discourage innovation. There are high cost and risks of biotech research and emerging industries need incentives to invest in new ideas. In addition, patent and royalty laws need to catch up with technological innovations so markets can perform better (Duca et al,2002).

Biotech research is interdisciplinary in nature. Current biotech science draws on advances in chemistry, biology, computational methods, and medicine to develop new therapeutics. Looking ahead, the interplay of advances in biotechnology, informatics, and nanotechnology could extend biotech applications to an array of products and services inconceivable only a short time ago, greatly improving quality of life and boosting economic growth.

7.Regulatory Authorities of Biotechnology:

There are significant differences in the kinds of regulatory approaches countries adopt on biotechnology. The United States has adopted a regulatory approach closest to a laissez-faire model. The Food and Drug Administration (FDA) issued a policy statement in 1992, in which it established that biotech products were generally considered to be as safe as conventional food and that pre-market approval was only necessary under certain conditions. The great majority of countries have, so far, adopted some form of regulation on biotechnology and biotech products. The core elements for regulation on biotechnology include laboratory control, environmental release, risk analysis, and socio-economic considerations for pre-marketing authorization; also, subject to regulation are labelling, traceability and other monitoring measures for post-approval surveillance. Risk analysis covers risk assessment, risk management and risk communication. Precautionary action is also provided for in the risk analysis and regulatory systems of most countries. These measures are expected to allow for a high level of protection of human health, environment and eco-system. These measures at the national level are illustrative of a global trend, which has led to the adoption of several international instruments to address the adverse effects of Genetically Modified Organisms(GMOs). The potential of biotechnology to contribute to the alleviation of some problems associated with development and the environment was recognized by the 1992 UN Conference on Environment and Development (the "Earth Summit"), which devoted Chapter 16 of Agenda 21 to "Environmentally sound management of biotechnology." In addition to providing the basis for future negotiation of a specific protocol on biosafety, the Convention on Biological Diversity requires Contracting Parties to establish or maintain specific means to regulate risks associated with GMOs. Article 8(g) of the Convention thus required Parties, as far as possible and as appropriate, to establish or maintain means to regulate, manage or control the risks associated with the use and release of living modified organisms resulting from biotechnology which are likely to have adverse environmental impacts that could affect the conservation and sustainable use of biological diversity, taking also into account the risks to human health. This provision reflects a common view that “living modified organisms” are not the same as their non-GM counterparts, and that they have characteristics which inherently require the assessment of human and environmental risks. Many international agreements relating to biotechnology are legally binding or strongly political consensus,

8.Biosafety:

Biosafety refers to containment principles, technologies and practices that are implemented to prevent unintentional exposure to pathogens and toxins, or their accidental release into the environment. Biosafety is not only a personal requirement but essential collective efforts to ensure biological safety for a clean and safe environment. In the last few decades, biotechnology research has resulted into the development and release of several GMOs for commercial uses. Releasing GMOs into the environment may have direct or indirect effects including gene-flow or gene-transfer to wild relatives, trait effects on non-target species, pest resistance and other unintended effects. One of the most significant environmental benefits of GM crops is the drastic reduction in pesticide use in agriculture. Despite their potential, there is a multitude of concerns about the impact of GM crops on the environment. With the increasing number of countries adopting molecular tools and techniques in their life science research and development activities, the biosafety issues are gaining importance to ensure biological safety for the public and the environment. Recognizing the need of biosafety in GE research and development activities, an international multilateral agreement on biosafety “the Cartagena Protocol on Biosafety (CPB)” has been adopted by many countries world over(Kumar,2015)

9. Biosecurity:

The term biosecurity is more complex as it can have different meanings different contexts. According to the WHO guidance, biosecurity refers to the mechanisms to establish and maintain security and oversight of pathogenic microorganisms, toxins and relevant resources. Laboratory biosecurity describes protection, control and accountability for valuable biological materials within the laboratory, in order to prevent their unauthorized access, loss, their, misuse, diversion or intentional release. While biosafety protects people from harmful germs, biomolecules or chemicals, biosecurity protects such materials from people. The approaches used to achieve them are often similar or mutually reinforcing, but in some cases, they may have conflicts. For example, in the transportation of dangerous pathogens, biosafety recommends clear labelling of the material during transport, but from a biosecurity perspective, labelling of the material during transport may increase the risk of their or misuse. HH Issues With the increasing emphasis on adoption of GE technology, biosafety issues are gaining importance to ensure safety of the public and the environment. There has been increasing awareness among the researchers, producers and users of GMOs, administrators, policy makers, environmentalists and general public about biosafety. Therefore, many countries have put into place regulatory policies and regulatory bodies for research and development of GMOs, however strict compliance to biosafety guidelines is still required in many developing countries. Though there are several technical issues of releasing GMOs in the environmental for commercial uses, safety of the laboratory workers, consumers and the environment as a whole is the biggest issue. As per a report, containment facility in the laboratories across the Asia-Pacific region often failed to live up to the term. Biosafety and biosecurity issues became much stricter from 2001, when anthrax attacks in the United States raised the spectre of bioterrorism using laboratory-prepared pathogens. Unfortunately, stringent biosafety and biosecurity rules are still impractical in many countries, where researchers often need to handle infectious agents such as anthrax and plague to protect public health, but lack the proper infrastructure. It is clear now that modern biotechnology promises to enhance the quality of human life, if used judiciously. On the other hand, if used haphazardly and carelessly, it may have negative impacts as well. Biosecurity is the need of the day, as bioterrorism is another associated concern emerging rapidly and need to be taken care in the interest of the sustainable research and development as well as for healthy and safe environment(Kumar,2015).

10.Success of Biotechnology:

The insect resistant (IR) technology, used in cotton and corn, deliver yield gains from reduced pest damage. The herbicide tolerant (HT) technology contributes to increased production, improve weed control and provide higher yields in some countries and help farmers. Crop biotechnology helps farmers earn more secure incomes mainly due to improved control of pests and weeds. The net farm level economic benefit in 2014 was $17.7 billion, equal to an average increase in income of $101/hectare. The highest yield gains continue to be for farmers in developing countries, many of which are resource-poor and farm small plots of land.

Crop biotechnology continues to be a good investment for millions of farmers. Farmers in developing countries have received $4.42 for each dollar invested in GM crop seeds in 2014 (the cost is equal to 23% of total technology gains), while farmers in developed countries received $3.14 for each dollar invested in GM crop seed (the cost is equal to 32% of the total technology gains). The higher level of technology gains realised by farmers in developing countries relative to farmers in developed countries reflects weaker provision of intellectual property rights coupled with higher average levels of benefits in developing countries; Between 1996 and 2014, crop biotechnology was responsible for additional global production of 158.4 million tonnes of soybeans and 321.8 million tonnes of corn. The technology has also contributed an extra 24.7 million tonnes of cotton lint and 9.2 million tonnes of canola.

GM crops are allowing farmers to grow more without using additional land. If crop biotechnology had not been available to the (18 million) farmers using the technology in 2014, maintaining global production levels at the 2014 levels would have required additional plantings of 7.5 million ha of soybeans, 8.9 million ha of corn, 3.7 million ha of cotton and 0.6 million ha of canola. This total area requirement is equivalent to 12% of the arable land in the US, or 33% of the arable land in Brazil or 14% of the cropping area in China (Brooks and Barefoot,2008).

Crop biotechnology has contributed to significantly reducing the release of greenhouse gas emissions from agricultural practices. Use of crop biotechnology has decreased the environmental impact associated with herbicide and insecticide use on the area planted to biotech crops by 18.5%.

11.Ranking the Top Biotech Countries

The United States ranks first in the number of biotech firms, PCT patent applications, and biomedical treatment approvals, with Spain coming second, according to the 2015 OECD report on biotechnology statistics. According to the report, the U.S. has 11,367 biotech firms followed by 2,831 in Spain and 1,950 in France. They are followed by Korea, Germany, United Kingdom, Japan, Mexico, New Zealand and Belgium rounding out the top 10. Small biotech firms are the rule rather than the exception, with 72 percent of the biotechnology firms in the United States having 50 or fewer employees

11.i. Ranking by Total Biotechnology R&D Expenditures

The number of firms is one way to rank biotech by country, while expenditures in research and development are another. The United States outspends its nearest competitor, France, by eight to one, at almost $27 billion to a little over $3 billion in 2012. The other big spenders are Switzerland, Korea, Japan, Germany, and Denmark at all over one billion dollars (Hall et al,2007).

12.The Changing Landscape for Research and Development

However, research and development budgets have felt the squeeze in the European Union, Japan, and the United States since 2008, with only 1.6 percent annual growth rate on average in 2008 through 2012. Meanwhile, China continues to boost its spending on R&D in general, doubling it between 2008 and 2012.

As a result, it’s expected that China will be the leading spender in R&D by 2019, according to OECD. The 2012 report found that public finances were still tight in many countries, so they weren’t able to boost R&D budgets with public funding as was done at the height of the economic crisis in 2008-2010(Hall et al,2007).

According to the 2010 OECD report on science and technology, however, it appears the industry picture has looked better in later years for several non-OECD countries, including Singapore, Brazil, China, India and South Africa.

Although Japan is ranked second for a number of criteria by OECD, it doesn’t rank in the top 5 at all according to other sources and criteria. In August 2010, Scientific American ranked the top 5 biotech countries in a “Worldview Scorecard” as being USA, Singapore, Canada, Sweden and Denmark, using the following criteria: IP and ability to protect it, intensity, being defined as spending on R&D, availability of venture capital and support, availability of expert manpower and the overall country’s ranking in terms of entrepreneurship and other foundations. Countries doing well are those with strong incentives for technology development and a range of options for obtaining research funding (OECD Report,2015).

China and India rank as the top two countries for increasing gross domestic product (GDP) during what was referred to as the Global Recession of the past 2 years (Global Biotechnology Report ,2010).

The stats suggest that China will soon become the third largest pharmaceutical market after the USA and Japan, and, being a popular (inexpensive) spot for outsourcing, will do well in coming years. India also benefitted from downsizing and cost-cutting in other nations during the recession, due to its highly skilled workforce and lower manufacturing and research costs.

13.Ranking of India in Biotechnology

India is currently amongst the top 12 biotechnology destinations in the world and ranks third in the Asia-Pacific region. Despite the economic downturn in 2013 to 2014, the industry has experienced rapid growth due to increasing foreign investments, supportive government policies, increasing exports and a skilled workforce. India’s biotechnology industry is in a great position to transition to bio-economy. This will allow India to re-establish cornerstones defining the competitiveness of existing sectors, providing them with a favourable setting to operate and grow.

A recent white paper from Frost & Sullivan, India Ripe for Biotech Industry Growth, finds a fertile ecosystem will enable India to enter the biologics market, which is expected to reach $314.8 billion at a compound annual growth rate (CAGR) of 8.4 percent. India is a global leader in the world generics market, and with its strong positioning to provide affordable healthcare, biosimilars will be a perfect fit for Indian companies (Frost and Sullivan,2016).

The country has the essential ingredients for success, including:

- Top-ranked universities discovering and developing new technologies
- The formation of new companies
- The expansion of established companies
- Introduction of new products in the market
- A capable workforce
- An improving quality of life

The creation of competitive products and services as well as legislation will direct the paradigm shift from biotechnology to bio-economy. It is vital that new policy actions support the growth of a sustainable bio-economy.

Furthermore , it is essential to address the critical issues:

- Establish a simplified and efficient business process to encourage large-scale foreign direct investment.
- Re-evaluate biodiversity laws seriously impacting entrepreneurial efforts to create new industries and jobs locally.

14.Dealing Biotechnology in Future:

Biotechnology and its aspects are mostly technical in nature. So, in order to address the issues that involves greater participation of the companies and people there are sets of complex governance issues that needs to be addressed. The below mentioned ideas not only target the technical part but also considers the governing aspect of it too.

- **Providing and promoting consulting services** through various regional, national and international commissions leads to greater participation rate among the interested groups and helps in exchange of ideas benefiting wider target group. Eventually people become more aware of the recent advancements made in the field of biotechnology.
- **Encouraging and promoting assessment systems** between various stakeholders for better understanding and encouraging confidence.
- **Promote research and organise training programmes** for building new ideas as well as spreading it to more number of interested institutions or

individual. New innovative concepts and designs enriching our existing knowledge pool, improve understanding and enhance technology management capabilities.

- **Knowledge Transfer from developed to developing countries** as they need to formulate policies and strategies that seek to maximize the benefits of emerging technologies and minimize their risks. Furthermore, technological cooperation has the potential to reduce international tension over access to genetic resources(Juma,1999)

15. Conclusion:

Scientific leaders in the development of agricultural biotechnology can contribute to the economic growth of many countries by commercializing goods and services possessing improved modified characteristics. The potential for increased production and decreased costs in the economy is the main effect of introduction of biotechnology. But limited resources, the high cost of research, and the undesirable effects of past adoptions of technology have made the public and research community more aware of the importance of evaluating other economic impacts before adopting the new biotechnologies. Additional information is needed about the price and income effects of the increased production and about who gains and who loses market share, income, and welfare **-** the distributional effects of economic change.

The U.S. Department of Agriculture (USDA) and the Office of Technology Assessment of the U.S. Congress have studied the impacts of agricultural biotechnology and other modern technologies. But most of the studies have avoided the issues of the changes in income and welfare among firms, regions, and economic sectors as the technologies have been commercially adopted.

Policy analysts of economic and social consequences have often relied on qualitative evaluation without quantifying the results. Useful insights into relationships among the important variables can be obtained by quantifying at least those consequences that from direct changes in the quantities produced. Subsequent changes will cause additional adjustments in quantities, and the ripple effects quickly go beyond the capacity of simplifying mathematical models.

REFERENCES:

A. Messeni Petruzzelli, D. Rotolo, V. Albino, (2012), "The impact of old technologies on innovation: the case of the US biotechnology industry", *Technology Analysis and Strategic Management*, 24 (5) 453–466.

B.H. Hall, G. Thoma, S. Torrisi, (2007), "The market value of patents and R&D: evidence from European firms", *NBER Working Paper No. 13426*.

D. Archibugi, J. Michie, (1995), "The globalization of technology: a new taxonomy", *Cambridge Journal of Economics*, 19 (1) 121–140.

F.T. Rothaermel, M. Thorsby (2007) "The nanotech versus the biotech revolution: sources of productivity in incumbent firm research", *Research Policy*, 36 (6) 832–849.

John V. Duca and Mine K. Yüce(2002), *Exploring the Economics of Biotechnology: An Overview.*

J.M. Birkinshaw, G. Hamel, M.J. Mol, (2008), Management innovation, *Academy of Journal Management*,33 (4) 825–845.

Hill, L and Florkowski,W(2007) "The Economics of Biotechnology in Field-Crop Production", *Office of Agricultural Communications and Education*, (217)333.

M.L. Tushman and L. Rosenkopf, (1992) "Organizational determinants of techno- logical change: towards a sociology of technological evolution", *Research in Organizational Behaviour*, 14,311–347.

M. Trajtenberg, Economic Analysis of Product Innovation, Harvard University Press, Cambridge, MA, 1990.

Brookes, G and Barfoot,P(2008) "Global Impact of Biotech Crops: Income and Production Effects 1996-2007",*Journal of Agrobiotechnology Management and Economics*,12(2).

W. Zidorn, M. Wagner, (2012), The effect of alliances on innovation patterns: an analysis of the biotechnology industry, Ind. Corp. Chang. 22 (6),1497–1524.

Amini, S., Sharafi,S., Komeili,H and Tabaee,N(2014)," Effect of biotechnology on biodiversity", *International Journal of Farming and Allied Science.*

Shah,M(2014)"Environmental Bioremediation: A Low Cost Nature's Natural Biotechnology for Environmental Clean-up", *Petroleum & Environmental Biotechnology*.

OECD (2015) "Biotechnology, Innovation and Health", *Directorate for Science, Technology and Innovation.*

Kumar,S(2015), "Biosafety and Biosecurity Issues in Biotechnology Research" ,*Biosafety*.

Juma,C (1991), "Biotechnology in the global Economy: Beyond Technical Advances and Risks", *The Journal of Biotechnology Management and Economics*,2(3),218-222.

Biodiversity Factsheet (2013), California Climate and Agriculture Network (CalCAN).

Beyond Borders: Global Biotechnology Report (2010), Ernst and Young.

Frost & Sullivan White Paper (2016) "India Ripe for Biotech Industry Growth Government Incentives, Investments Leading Transition to Bio-Economy", *BIO International Convention.*

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The Ministry of Environment and Forest, Government of India has designated Madras School of Economics as a Centre of Excellence in the area of Environmental Economics. The Centre carries out research work on: Development of Economic Instruments, Trade and Environment, and Cost-Benefit Analysis. The Centre is primarily engaged in research projects, training programme and providing policy assistance to the Ministry on various topics. The Centre is also responsible for the development and maintenance of a website (http://coe.mse.ac.in), and for the dissemination of concept papers on Environmental Economics.

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Madras School of Economics was founded in 1993 as a private postgraduate institution for teaching and research in economics. MSE offers a two-year Master's program in Economics, Financial Economics, Applied Quantitative Finance, Actuarial Economics and Environmental Economics affiliated to the Central University of Tamil Nadu, and a Ph.D. programme affiliated to Madras University. MSE has undertaken a large number of research projects since its inception, including the World Bank sponsored Capacity Building Programme in Environmental Economics. The World Bank project involved research, training, curriculum, and overseas fellowship components which were coordinated by MSE. Subsequently, the Ministry of Environment and Forests approved the proposal to set up a Centre of Excellence in Environmental Economics at MSE. MSE has also served as an ENVIS Centre in Environmental Economics under the Environment Information System (ENVIS) of the Ministry of Environment and Forests, Government of India. A dedicated program on Trade and Environment, with support from the Ministry of Environment and Forests, Government of India, has been initiated at MSE.

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