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Blue biotechnology potential in Tunisia - a preliminary study of national stakeholders' involvement in setting priorities



by

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with the support of



1. Introduction

The development of green (and blue) economies is a priority issue in policy-makers agenda worldwide. The spurring of green and blue economies has two main implications. The first is designing productive systems that use the natural capital in a sustainable way. Sustainable, in economics, is an intergenerational concept: it implies leaving at least the same stock and quality of environmental/natural capital to future generations. The second implication refers to creating an economic sector that adopts natural capital as productive inputs, in order to generate new income sources in a “green” (or blue) way. The market for biotechnology is a typical example of a sustainable market in a green economy, where a strong link with science advances is required. Biotechnology markets are increasing fast in OECD countries (see the 2009 OECD report). North European and Middle East countries are undertaking parallel initiatives to support biotechnology as powerful tools for their economical growth.

In Israel, the Government recognized the sector as a priority since the late 1990s and undertook bilateral joint initiatives first with the USA, then with many EU countries. Today Israel is keen to expand its market distribution areas. Algeria is developing the sector *ex novo* (i.e. Algerian 2007-2013 funding plan prioritizes biotechnology). Finally, Egypt and Tunisia seem to invest exponentially in the ‘nanotechnology’ and the ‘biotechnology’ sector, respectively. Tunisian effort at the level of infrastructure is noteworthy, with special reference to the ‘Sidi Thabet Technopark’, devoted to Biotechnology applied to health and pharmaceutical Industries.

This contribution focuses on the Tunisian experience which shows many signs of growth and interest in this sector. In November 2002, Tunisia established the Sidi Thabet Technopark, devoted to biotechnology applied to health and pharmaceutical Industries, which offers a new form of partnership between research, innovation, training and production with technological connotation. Sidi Thabet belongs to the network of ten Technoparks being established in Tunisia to create new research and economic potentials. Other important institutions, oriented on biotechnological research, are the following:

- Sfax (CBF), working since 1983 on bio-engineering of bio pesticides and wastes treatment;
- the Pasteur Institute, working since 1988 on bioprocess of toxins and bio-therapeutics;
- INSTM (National Institute of Marine Science and Technology), working since 1999 on microbial bioremediation, microbial bioactive products, wastes biotransformation.

These centres are too recent and factual information about biotechnology is too fragmented and scarce to do a robust valuation of the sector performance. But we have information about the output of selected research centres (e.g. the Centre de Biotechnologie de Borj-cedria (CBBC) states 161 university diplomas (including PhD) and 352 articles). The total number of PhD graduates in biotechnology is not clear. Yet, biotechnological institutes and techno-poles are very active. The Centre de Biotechnologie de Sfax (CBS) lists 17 patent applications. The CBBC states 17 patents. Vaccines and serums are patented by the Institut Pasteur of Tunisia. Successful experiences come from agricultural companies that produce biotechnology nurseries. One such example is « Mabrouka » Trees and plants nursery Kheledia, north of Tunis. Covering 150 hectares, the company employs three engineers and many technicians besides 150 to 250 workers. The nursery has a leading biotechnological laboratory. Currently, « Mabrouka » produces millions of olive trees, and is developing approximately, 500 000 new plants such as the *Paulownia tomentosa*.

With respect to marine biotechnologies, to our knowledge, Tunisian marine biotechnology research is carried on mostly at INSTM Departments, in five different research teams: one team in Carthage (pharmaceutical and health sectors, fishery and aquaculture); two in the Goulette Center (biotransformation of marine wastes and bioenergy); one in the Kheireddine Center (macro-algae

biotechnology and their bioactive products) and the last one in the Monastir center (thermophilic microalgae and bioproduction). Other research teams partially deal with marine biotechnology :

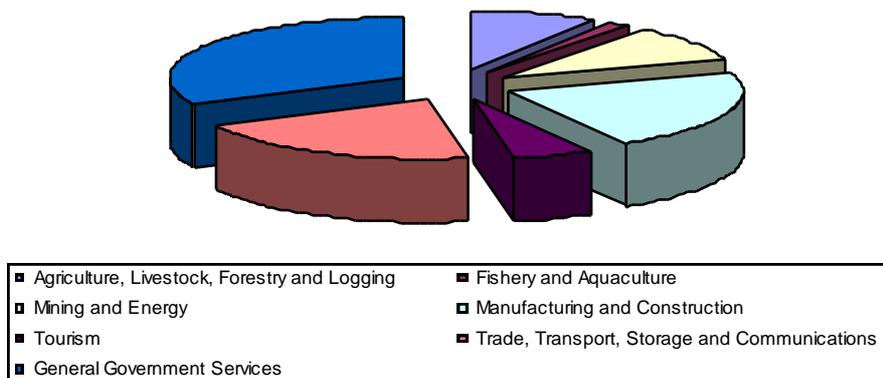
- the National Institute of Sciences and Technology (INSAT), with one team focusing on thermo-tolerant microorganisms;
- the University El Manar, with some research on bioactive products in sponges and halophile cyanobacteria); and
- the Center of Biotechnology of Sfax, where a research team is focusing on aquatic microalgae and biovalorisation.

The present contribution discusses the perspectives of sustainable economic development of the biotechnology sector in Tunisia, based on available socio-economic and environmental data, and perceived strengths and weaknesses.

2. Tunisia at a Glance: Economy Structure

This section, based upon the latest available World Bank and Tunisian Ministry of Development and International Cooperation annual data (2010), provides a snapshot of Tunisia's economy structure and human capital characteristics, in order to inform out preliminary analysis of biotechnology markets in Tunisia. The indicators, in fact, provide synthetic information about the country macroeconomic scenario and the performance of the economy. Tunisia is a developing country with a good economic performance. It is considered an upper middle income country: in 2010 the total gross domestic product (GDP) accounted for 44 billions in current U.S. dollars, with a growth rate of 4.2%. Though still experiencing some degree of poverty, with 3,8% of the population living below the poverty line, the economy is growing at a larger rate than EU Member States economies. Tunisia has a diverse economy, with important agricultural, mining, tourism, and manufacturing sectors. Governmental control of economic affairs while still heavy has gradually lessened over the past decade with increasing privatization, simplification of the tax structure, and a prudent approach to debt. Progressive social policies also have helped raise living conditions in Tunisia relative to the Northern Africa region. Real growth, which averaged almost 5% over the past decade, declined to 4.6% in 2008 and to 3-4% in 2009-2010 because of economic contraction and slowing of import demand in Europe, Tunisia's largest export market. However, development of non-textile manufacturing, a recovery in agricultural production, and strong growth in the services sector somewhat mitigated the economic effect of slowing exports. Tunisia will need to reach even higher growth levels to create sufficient employment opportunities for an already large number of unemployed as well as the growing population of university graduates. The challenges ahead include: privatizing industry, liberalizing the investment code to increase foreign investment, improving government efficiency, reducing the trade deficit, and reducing socioeconomic disparities in the impoverished south and west. Figure 1 describes the 2010 GDP composition per economic sectors.

Figure 1 : 2010 GDP Sector Composition.



The Tunisian economy mostly hinges on tourism (5.5%), mining and energy (9.6), agriculture (8.9%), manufacturing and construction (21.9) and exports to the EU (around 20%). The economy is based on market-driven economic reforms launched in the late 1980s, even if almost one third of GDP still depends on the public sector expenditures¹.

2.1. Blue Economy in Tunisia

Tunisia, occupying a central place in the Mediterranean, opens up widely onto the sea, mainly on its eastern shores. It has more than 1.300 Km of coastline, for an area of 163.610 km.

The blue economy is very important in Tunisia, and is mostly sustained by (coastal) tourism, maritime transportation, fishery and aquaculture. We can roughly estimate that around one fourth of the Tunisian economy depends on marine services, for an estimated total value of around 11 billion USD in 2010, of which around 8 billion USD from the maritime transport; 2.5 billions from the tourism sector and 0.6 billion USD from the fishery and aquaculture sectors.

The geographical position of Tunisia, between two sub-basins of the Mediterranean, provides many advantages in terms of the country’s value to the European market. Maritime transportation is an important factor for the competitiveness of Tunisian exports. About 95 percent of international trade of goods from and to Tunisia is shipped, and the volume of its trade (exports and imports) is worth close to 80 percent of its GDP. Tunisia’s maritime transport sector provides 92% of trade internationally and 98% nationally. More than 80 transit companies and 400 maritime and port companies participate in Tunisian imports and exports. Maritime transportation is carried on in the harbors of La Goulette, Sfax, Sousse, Bizerte, Gabes, Zarzis, among the others, and benefits from a very competitive price strategy with respect to other Mediterranean competitors² (source Boughzala, 2005).

The coastal tourism sector, with around 7 million arrivals and 239,890 bed-places all over the country in 2010 (source: World Tourism Organization statistics), is mostly specialized in three main segments: (1) coastal recreational (beach tourism); (2) cultural tourism (with the presence in Tunisia of eight cultural and natural UNESCO sites, on the coast or near the cost: Amphitheatre of El Jem; Archaeological Site of Carthage; Dougga / Thugga ; Kairouan; Medina of Sousse; Medina of Tunis; Punic Town of Kerkuane and its Necropolis; Ichkeul National Park); (3) health/thermal tourism (marine health and beauty cares, thalassotherapy that exploits the Mediterranean Sea benefits in 35 centers).

Fishery and aquaculture are not “strong” economic sectors *strictu sensu*, since they contribute to a low percentage of the national GDP (only 1.4% and fishery is a highly governmental subsidized activity). Nevertheless, in Tunisia, fisheries and aquaculture play an important role in socio-economic terms as a source of food: differently from neighboring countries, like Morocco and Algeria, Tunisian alimentary habits broadly include fish consumption. Annual per capita consumption, for instance,

¹Tourism is a significant source of revenue and foreign exchange. The mining and minerals industry produces iron ore and phosphate, (excluding oil and gas), together with other industrial activities (textiles, footwear, agribusiness, beverages) Agriculture products are: olives, olive oil, grain, dairy product, tomatoes, citrus fruit, beef, sugar beets, dates, almonds. Finally, the manufacturing sector is the sector with the highest annual growth is rate (4.4%), followed by the industry (4.1%) and the agriculture (3.5%) sectors.

²Tariffs for Maritime Transport in selected Mediterranean Sea ports (source (Boughzala, 2005).

Table 1: Comparative shipping cost from Tunis, Casablanca and Alexandria to European ports in 2003 (for a 40’ container including freight and port services) (costs in euros)

	Marseilles	Genoa	Barcelona	Antwerp
Tunis	1117	999	1154	1148
Casablanca	1212	1193	1149	1351
Alexandria	836	778	833	779

Source: Republic of Tunisia, Ministry of Transportation, “Les statistiques du secteur maritime et portuaire en Tunisie” 2002-2003.

passed from 8.5 kilos per person in 1990 to 9.5 kilos per person in recent years (source: FAO statistics). This is why fishery production has never ceased to increase year after year, reaching the annual fishery catch of 110 tonnes. (see FAO statistics).

Aquaculture current production levels are about 3700 tonnes, accounting for almost 3% of Tunisia fish production. Both inland and marine species are currently being farmed. Most of the production comprises native species, even if some species have also been introduced, such as the zander; largemouth black-bass; silver carp; Nile tilapia and Pacific cupped Oyster. Aquaculture in Tunisia is not developing at the pace expected by the public authorities, despite the substantial potential that has been identified. Even though, aquaculture products are commercialized both internally (for household and tourism consumption) and on international markets, in particular the EU (seabass and gilted seabream, shellfish) and Japan (fattened blue fin tuna). (source: FAO statistics). In Tunisia, the aquaculture sector provides stimulus for applied research in marine biotechnologies. Aquaculture is, in our opinion, the most promising economic sector, whose development strongly depends on scientific achievements in blue biotechnologies.

3. Research and Economic Growth in Tunisia

Within the socio-economic context outlined above and prior to describing in more detail the policies adopted by Tunisia for supporting research in the biotechnology sector, we provide a preliminary analysis of the nature of the Tunisian productive capital and its possible adaptation to biotech sector development. In most macroeconomic models (e.g. endogenous growth, exogenous growth) economic (total or per sector) growth depends on three fundamental variables: financial capital, human capital; and natural capital (endowment). We examine here the characteristics of such variables in the case of Tunisia and the potential development of the biotechnology sector as a driving force for socio-economic growth. We want to address the following question: given the actual state-of-the-art of the Tunisia financial, human and natural capital, how could these productive inputs be better employed for developing the biotechnologies field?

3.1. Financial Capital

Biotechnologies markets are capital intensive with a long path to commercial payback, spanning from 10-15 years for the pharmaceutical sector; to 8-14 for chemical pesticides; to 2-5 years for industrial enzymes (Laird. 1999).

In Tunisia, the financial capital for investment in biotechnology markets is provided by:

- a) The Government (with the creation and financing in the period 2002-2006 of six technopoles in the country, aiming at creating an appropriate environment for the transfer and dissemination of technological know-how, the use of research results and business development). The investment, however, only accounts of at least 0.6 to 0.16% of the GDP (source World Bank).
- b) Foreign investors from pharmaceutical units (e.g. Genopole Evry; the Medical Technology Cluster of Saint Etienne³, Nato⁴; International Cooperation Agencies⁵).
- c) Local banks the support particular projects (e.g. the partnership between the Institut Pasteur of Tunis, biotechnological firms and pharmaceutical industry units)
- d) EU FP7 funding schemes for particular projects and collaborations, in particular with France, Italy and Spain.
- e) Private local capital, encouraged by a system of tax incentives, through exemptions and discounts.

³ Both French firms are stable financing partners of the Sibi Thabet Technopole. (<http://www.biotechpole.rnu.tn/en/page.aspx?id=54>)

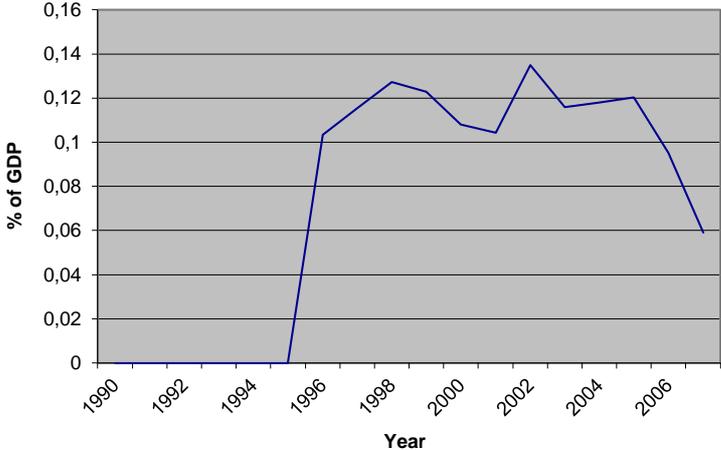
⁴ NATO Fellowship for research.

⁵ For example, the Institut Pasteur de Tunis collaborates with JICA (Japan International Cooperation Agency), the ATCT (Tunisian Agency for Technical Cooperation) and WHO (World Health Organization) for providing high education in biotechnology (marine genome) issues.

Evidence suggests that the diversity of financial resources allocated to the sector, will help to progressively reduce the State contribution and reinforcing those of the private sector and international cooperation. At the moment, however, we do not know the exact figures and the percentage quota, over the total, of each contribution. Further research, therefore, should focus on gathering more precise information on the financial capital sources and amount.

In Figure 2, elaborating Word Bank data, we show Tunisia (public and private) investment trends (as a percentage quota of total GDP) in research and development (R&D), in the period 1990-2007. Expenditures for R&D are current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development

Figure 2: R&D Expenditures



GDP percentage expenditures fluctuate over time, increasing from 1996, slightly decreasing in 2002, reaching a peak (0.13% of GDP) in 2003, and then decreasing (0.06% in 2007). Figure 2 (as well as the next figures) has a descriptive task: it summarizes descriptive information. The investigation of the reasons, underlying the trends, is beyond the objectives of the present preliminary note. It is important to highlight, however, that Tunisia GDP is constantly growing in the selected years. Therefore, the reason of the decrease in R&D expenditures should not be searched in economic crisis. On the contrary, we find an opposite relationship: an increase of GDP corresponds to a decrease of GDP share destined to finance research. In addition, it is interesting to highlight the orientation law on scientific research and technological development, dated January 1996, and its application decrees, facilitated the restructuring of the National R&D System through the creation of research laboratories and units in Public Research Institutions (PRI), Public Health Institutions (PHI) and Higher Education and Research Institutions (source UNESCO). The trend shows that the law objective to increase progressively internal expenditure allocated to the research system is well implemented. However, the further objective to reaching 1,25% of the GDP for R&D expenditures in 2009 seems far from achievement.

3.2. Human Capital

The 2010 total population is 10,550,000 people, with an average annual growth of 1% in the period 2003-2010. The 2010 gross per capita income is 3720 U.S. dollars. In terms of human capital profile and characteristics, the national poverty rate is 3.8%; the life expectancy is 74 years and the population literacy rate (of population older than 15) is 78%. 2010 total unemployment rate is 14.2%. The 2010 total labour force counts 3.769 million workers (with the 18.3% of the labour force employed in agriculture; 31.9% in the industry and 49.8 in the services sectors). The average annual growth of the labour force in the period 2003-2009 is 2.1%, Most Tunisians live in cities (with a 67%

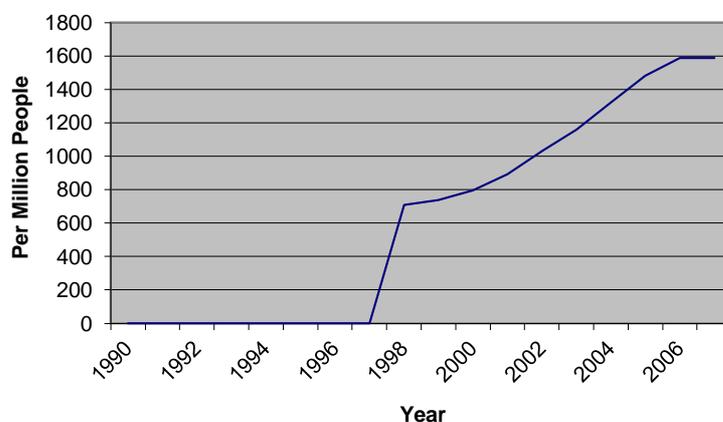
of urban population). 94% of the population has access to a water sources. Infant mortality is 42 (per 1.000 live births) and child malnutrition is 25% (children under 5).

The biotechnology sector requires specialized skilled work. In technical terms, this means that the marginal rate of substitution between a skilled worker and a non-skilled worker is very low. In non-technical terms, this means that it is not easy to adapt non-skilled workers in a field, where particular expertise is required (e.g. while it is possible and neither capital, nor time-intensive to convert a fisherman into a waiter for a touristic restaurant; this is not so straightforward for a researcher in biotechnology, unless a long and expensive investment in education is carried on).

The research sector is very active in Tunisia, with around 2000 researchers and 3000 teachers working in 75 laboratories in 300 research units. In Section 4, we have estimated the profitability of Tunisian researcher to R&D, which, given the data and selected time spam, is higher than capital productivity for high technology exports returns. This would imply that Tunisia specialized human capital and skilled labour is highly qualified and potentially productive.

In particular, we use UNESCO Institute for Statistics data to illustrate the trend of researchers in R&D per million people, in the period 1990-2007 in Tunisia⁶. Researchers in R&D are professionals engaged in the conception or creation of new knowledge, products, processes, methods, or systems and in the management of the projects concerned. Postgraduate PhD students engaged in R&D are included. Figure 3 illustrates the increasing trend of researchers employed in the R&D sector. In 2000, for instance, for every million Tunisian inhabitants, there were 800 researchers in R&D. After only six years, in 2006, the figure had doubled to 1600 R&D researchers for every million inhabitants. Again, Figure 3 conveys descriptive information, upon which we will elaborate some operational analysis in the further sections.

Figure 3: Researchers in R&D



3.3. Natural Capital

Some important natural capital assets (the total means of production, provided by the natural environment) might favor the development of the biotechnology sector in Tunisia, and notably:

- a) The typical Mediterranean climate conditions set an appropriate basis for the development of biotechnologies in the agricultural and algae production sectors. In this case, in particular, the application of biotechnologies to agricultural production systems (a sector where Tunisia is strong, and an exporting country) might generate a positive externality through switching to a more eco-friendly production system.

⁶ Observations are available from 1996, however, for the sake of comparability, we always consider the period 1990-2007

- b) The particular geographic position of the Gulf of Tunis and Gabes represent a peculiar situation, where the eastern and the western part of the Mediterranean Sea meet, generating a unique mix of condition waters, and marine organisms. This will be reflected in the specialized microbial communities that present a high potential development for marine biotechnologies.
- c) High productivity of the Mediterranean Sea, in terms of quantity and variety of fish landings (source FAO statistics)

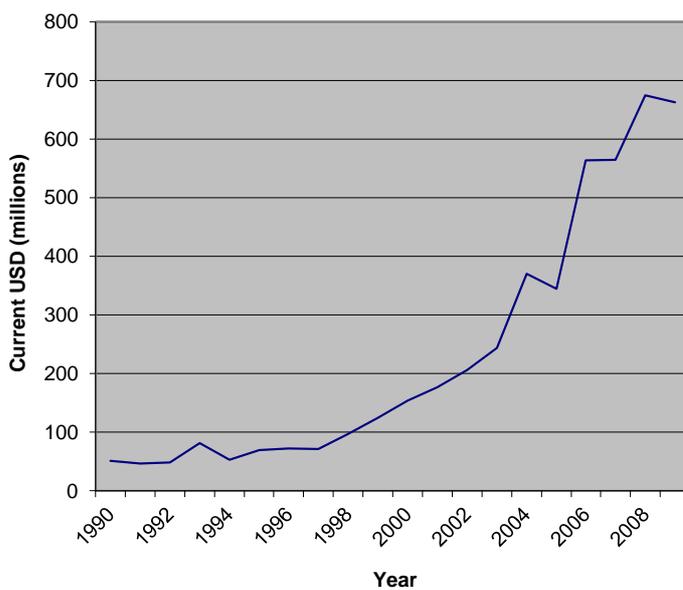
Assessing the economic value of natural capital in monetary terms is a complex operation. In particular, it refers to computing the economic value of the marginal productivity of the natural inputs in the productive system. For a recent demonstration study, see Nunes *et. al.* (2012)

3.4. Returns to Investment in R&D

It is interesting to assess what are the returns to (financial, natural and human) capital invested in R&D. In order to address the point, in the absence of ad hoc data for the biotechnology sector, we elaborate data from the World Bank and other sources, and study the trends of three selected indicators: (1) high technology exports revenues; (2) patents applications and (3) scientific and technical publications.

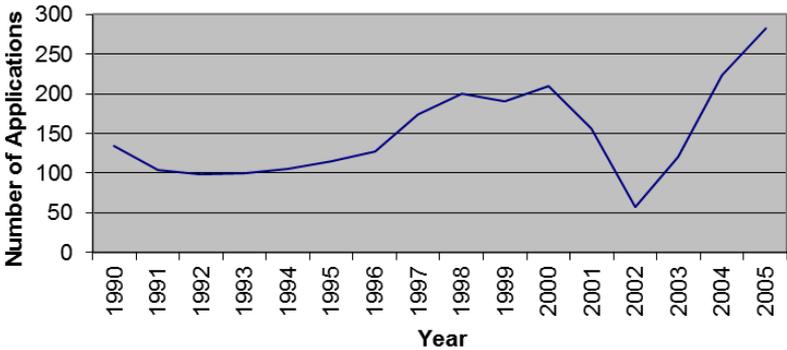
High-technology exports are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery. High technology exports generate revenues. According to the World Development Indicators of 2000, for instance, high technology exports constituted 11% of the manufacturing products, a very important sector in Tunisia economy. We use data (in current U.S. dollars) from the period 1990-2007. Figure 3 shows the trend of revenues generated by the export of high technology products. Revenues trends are overall increasing even if at different rates. We can disentangle three segments: constant trend during the first decade; returns increase at a constant rate between 2000 and 2004; increase at a decreasing rate thereafter. One possible reason of the described trend, (in particular of the revenues “boom in 1998-2003), can be found in the world economy expansion, occurring in the selected period (1998-2002).

Figure 4: High Technology Exports Revenues



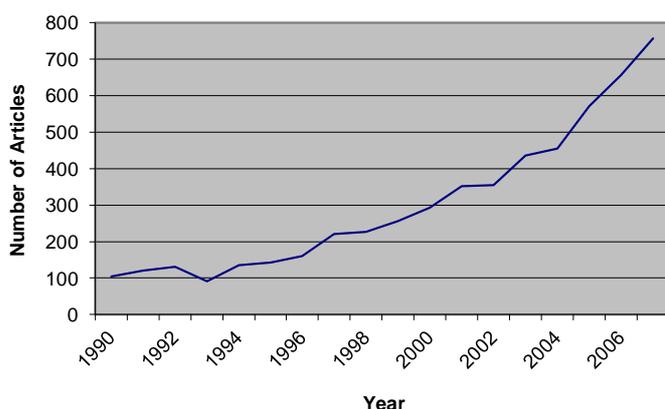
The economic exploitation of patents can generate high returns to the stakeholder of the exclusive rights. An indirect way to assess returns to investment in R&D can be provided by assessing the number of patents/patents application in a country. In Figure 5, World Intellectual Property Organization (WIPO) data are used for describing the trend of Tunisian patents applications from 1990 to 2006. These are filed through the Patent Cooperation Treaty procedure or with a national patent office for exclusive rights for an invention--a product or process that provides a new way of doing something or offers a new technical solution to a problem. A patent provides protection for the invention to the owner of the patent for a limited period, generally 20 years. Figure 4 shows a trend full of ups and downs in the considered period, with a peak of patents applications in 1999 and a minimum in 2001. In the field of biotechnologies, up to date, to our knowledge, the INSTM Monastir Center has obtained a national patent about spirulline bioactive products.

Figure 5: Patents Applications



Finally, another indicator that conveys information about the returns on investments in R&D is the number of publications in scientific and technical articles. Original research, in fact, is awarded by publication in refereed journals. In Figure 6, therefore, World Bank data are used to illustrate the fast-growing number of scientific and technical articles produced by Tunisian authors through the period 1990-2007. Scientific and technical journals considered comprise the following fields: biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences. It is straightforward to observe that the 1990 figure (100 articles) has grown eight times in only 16 years. It is also worth mentioning a UNESCO study, according to which the analysis of the publications data 1994-2004 shows that Tunisian institutions collaborate mainly with France. The USA and Italy follow. Further analysis of the collaborations shows that most are with European and North American countries. The analysis also revealed that there is limited collaboration with Sub-Saharan Countries compared to Arab and North African countries. Only six collaborations were recorded with South African institutions (see Madikizela 2006).

Figure 6: Scientific and Technical Articles



An overall assessment (through a visual check) of the performance trends (patents, revenues from R&D/high technology exports and number of publications) suggests that the Tunisian research sector is a growing field. However, in order to causally link and capture the relationship between investment in R&D (including biotechnologies) and sustainable economic growth in Tunisia, we need to further explore the available data and make the use of econometric analysis⁷.

3.4.1. Returns to Investment in R&D: Preliminary Empirical Analysis

We want to check the nexus of causality between the revenues generated by high technology exports and other variables that may (or may not) affect those returns, in turn, positively affecting the Tunisia GDP. In particular, we want to test the hypothesis that the revenues from high technology exports depend on the macroeconomic conditions of the exporting country (measured by the GDP); the work of specialized researchers and technicians; the capital invested in R&D. In order to test such hypothesis we need to define a statistical model and test the hypothesis/estimate the model with a selected estimation method. The technical details are provided by the technical annex in the document appendix. Once the model estimated and the diagnostics tests performed, we present and discuss the empirical results to check the procedure correctness.

Our empirical results suggest that human capital (researchers) and financial capital are crucial to (production and therefore) exports of high technological outputs. **In particular, a marginal (one percent) increase in the number of R&D researchers generates a 1.7% increase in the exports returns; a marginal (one dollar) increase in R&D expenditures generates a 0.85% increase in export returns.** In technical terms, we can state that the marginal productivity of (skilled) labour is higher than the marginal productivity of capital in the generation of revenues from the commercialization of high technology manufacturing. R&D researchers are, therefore, important inputs to the economic growth of Tunisia.

This result confirms an overall impression provided by the descriptive statistical data analysis: skilled labour can represent a valuable asset for the Tunisian economy, being a very productive input in the returns' generation of high technology exports, and (probably consequently) in the returns' generation in biotechnologies sectors. This is a very general result and should be deepened sector by

⁷ Econometrics is the statistical diagnosis (metron) of economic relationships, theory and models (econ). See Verbeek (2002).

sector with the availability of more and more detailed datasets. However, the results provide tremendous implications for R&D policy design: Tunisian R&D researchers efficiently contribute to the production of a high added value output. Therefore, proper policies (of which we will provide a short survey in the following section) should focus, not only at attracting financial capital in the R&D sector, but also at defining remunerations and organizing research in order to avoid “brain drain”. From our estimates, the loss of one researcher would have a higher negative impact on the economy than the loss of one dollar invested in R&D. In our opinion, this empirical result has a broad application. It would be, however, very interesting to adapt the general exercise to a sector by sector study, in particular, the blue biotechnologies field.

4. Policies supporting the Biotechnology Sector

We identify six major actions that together provided a favorable context to the growth of the sector:

- a) Adoption of policies supporting research and education, and promoting spin-offs and collaborative biotechnology research between industry and public research, through the Tenth Economic and Social Development Plan (2002-2006) stated for the creation of 6 techno-poles⁸ in the country, aiming at creating an appropriate environment for the transfer and dissemination of technological know-how, the use of research results and business development⁹.
- b) Initiatives supporting business courses in university degrees in biotechnology, through the creation of Higher Institutes of Biotechnology, where biotechnology applied to different themes is taught¹⁰.
- c) Stimulation of entrepreneurship through fiscal incentives¹¹, for the exploitation of public technology research.

⁸ Planned technoparks and their areas of focus include the following: (1) Mednine: Desert resources; (2) Jendouba: Forest products valorisation; (3) Gafsa: Phosphates; (4) Gammarrh: Cinema industry; (5-6) The Marine technologies network: Aquaculture, Biotechnology, Biodiversity and marine Environment. **For an excellent survey of Science and Technology stakeholders in Tunisia, see Mandikizela (2006)**

⁹ According to Law n°2001-50 of 3 May 2001, relating to Technological poles firms, as amended and completed by Law 2006-37 of 12 June 2006 (**Loi n°2001-50 du 3 mai 2001 relative aux entreprises des pôles technologiques telle que modifiée et complétée par la loi n°2006-37 du 12 juin 2006**), the definition of a technical pole entails a collaborative aim. The law afore stated, provides that a technological pole is “The **facility** or all facilities equipped for integrated activities in the field of training and scientific and technological research on the one hand, and the area of production and technological development on the other hand, in a specialty or a specific set of specialties, to promote the competitiveness of the economy and develop its technological components, and so, by encouraging technological innovation and supporting complementation and integration between these activities in the context of national priorities”.

¹⁰ The General Academic system is fixed by a Minister Decree, followed by Minister decisions of creation of specialized higher institute as follows:

Décret n° 2004-2722 du 21 décembre 2004, stating the studies and conditions for obtaining the degree in techniques and technologies specialties),

Arrêté du 16/01/2009: Institut supérieur de biotechnologie de Monastir - aquaculture, quality control of food and environment and development of natural resources,

Arrêté du 04/02/2008: Institut supérieur de biotechnologie de Monastir – Marine biotechnology,

Arrêté du 10/02/2007: Institut supérieur de biotechnologie de Sfax - Technology in biotechnology,

Arrêté du 02/09/2006: Institut supérieur des technologies médicales de Tunis – Medical biotechnologies and Electronic systems,

Décret no 2004-1391 du 22/06/2004: Institut supérieur de biologie appliquée de Mednine (applied biological sciences), Institut supérieur des sciences et des technologies de l'environnement de Borj-Essedria (Environment science and technologies) and, Institut supérieur de biotechnologies de Sidi-Thabet (industrial microbiology, quality control in agri-food and pharmaceuticals sectors).

¹¹ There exist different incentives schemes:

A Common incentives (Tax relief for shareholders up to 35% of profits or net revenue subject to corporate tax or personal income tax.; Tax relief on profits reinvested back into the company up to a limit of 35% of taxable corporate profits. · Exemption from Customs duties and similar taxes and VAT payments for imported equipment that has no locally manufactured equivalent; Suspension of VAT for locally manufactured equipment purchased before the enterprise enters

- d) Creation in 1999 of a public body (*Association Tunisienne de Biotechnologie*) that bridges the academic, research world with the entrepreneurship's reality. In addition, Tunisia established, in November 2002, the Sidi Thabet Technopark, devoted to biotechnology applied to Health and Pharmaceutical Industries, as a tool of interface and proximity between industrial and academic research.
- e) Granting of fiscal incentives (mostly to pharmaceutical industries), to support industrial development related to improving the availability of financial capital and various forms of business support for start-ups (e.g. concession of land and creation of access infrastructures to scientific poles¹², (e.g. project of supporting the industrial zone of the Biotech Pole Sidi Thabet, through the concession of 78 ha of public land situated in Monastir)
- f) Adoption of measures aiming at supporting the agricultural biotechnology cluster, through the creation of a network of 26 biotechnology agricultural nurseries (Réseau National des Pépinières d'entreprises) that work under the management and control of the national Agency promoting industry and innovation.

7. Conclusions

After considering the perspective for sustainable economic development of the biotechnology sector in Tunisia, we begin to identify both strengths and weaknesses. Our main results are summarized in Table 1.

Table 1: Biotechnologies Sector in Tunisia: Strengths and Weaknesses for the Sector Development

	Strengths	Weaknesses
Financial Capital	Macroeconomic stability, guaranteed by international agencies (WB, IMF)	Political instability discourages foreign investors; Developing country
Human Capital	Highly specialized human capital; intensive Government investment in advanced education	Not enough capital investments and remuneration at the marginal productivity of labor might favor "brain drain"; high unemployment levels in the segment of young skilled workers with high education.
Natural Capital	Sunny and mild Mediterranean climate; favorable, unique geophysical and ecological conditions in the Tunis and Gabes Gulfs; high productivity of the Mediterranean sea (fish catch).	Current economic activities (maritime transport; polluting agricultural production techniques ; over-fishing) deplete natural capital

into production. Payment of VAT for locally acquired equipment after production start-up activity. Total or partial assumption by the State of expenditure for training).

B. For companies that export 100% of production (Full exoneration of income and profits from the tax base during the first ten years of activity and a 50% deduction thereafter, The liberty to import free of customs duties and taxes the equipment necessary for production; Total exoneration from registration fees, stamp duty and value added taxes on the activities of the enterprise)

C. For partially exporting companies: (Suspension of value added taxes and consumption taxes on equipment, products and services necessary for the realization of their export operations. Reimbursement of customs duties and taxes paid on raw materials and semi-finished products destined to be transformed for export. Reimbursement of customs duties and similar taxes paid on imported equipment, and not manufactured locally, for the production of goods for export.

D. Additional advantages (investment premium): (Major activities with high added value and a high integration rate. Investment in education and higher education, including student housing, vocational training. Investment in business incubators).

¹² Loi no 71-59 du 29/12/1971. (Law 71-59 of 29/12/1971. Part 1. Chapter 2: articles 1,2,3 and 27); Loi n°2001-50 du 03/05/2001 (relating to technological poles companies); Décret n°97-708 du 28 avril 1997, (decree by which a pharmaceuticals laboratory, "Dar Essaydali, is provided incentives)

In terms of economic development of the biotechnology sector, Tunisia's strengths stem from the highly productive skilled labour and the existence of peculiar natural capital assets. The weaknesses refer to political instability and the fact that Tunisia is still (according to the World Bank/International Monetary Fund criteria) a low/middle income country, still developing. This might favour brain drain and the loss of valuable human capital. Highly qualified researchers, in fact, might be willing to be paid at their marginal productivity and choose to go, therefore, in those markets where work marginal remuneration is higher.

Table 1 highlights strengths and weaknesses of the investment in science and technology sectors as spurring engines for Tunisia economic growth. If we want to focus on biotechnologies, in particular blue biotechnologies, we can only remark some points, since at the moment, information in Tunisia and in most other countries, is still scarce and too fragmented for performing an in-depth study.

However, we can suggest three main economic policy actions, with a twofold objective in mind. First, we want to highlight those research sectors that are better targeted to the Tunisia (blue) economy. Second, we would like to pave a discussion that lead to further research, mostly aiming at an accurate gathering of sectoral data. We remain focused on marine biotechnologies, although biotechnology practices and applications have been so far concentrated in the food and agricultural sectors, with the award of a patent on spiruline bioactive products and many successful stories for the biotechnology methods applied to olive trees and other agricultural cultivars. Biotechnology applied to the agricultural sector is an important strategic choice, since agriculture produces about 8-10% of total GDP, depending on the selected year.

Marine biotechnologies in Tunisia, though less developed, can have a valuable impact if interfacing to key economic sectors, for instance, aquaculture and thermal/health tourism.

In Tunisia, there exists extensive research carried on in the field of marine algae that contain antioxidants, pigments and vitamins increasingly used in cosmetic products. They are also a source of natural, non toxic colours (*i.e.* orange pigments from Chlorophyta, blue and red pigments from Rhodophyta). In addition, fish extracts are broadly used in cosmetics. In addition, cosmetic companies are able to produce a variety of smells and flavors once impossible to make in the lab. The future of flavor production lies in new metabolic pathways or fermentation methods that might be isolated from the sea. Several enzymes from marine organisms are certainly responsible for producing tastes and smell that might be the linked not only for food, beverages or perfumers (source CIESM 2011 Report).

The link between marine biotechnologies applied to wellness and thermal/health tourism might have a double positive impact on the economy; spurring research that can, in turn, generate incentives to specialize in a particular niche of the tourism sector, and therefore, present a comparative advantage with respect to Mediterranean competition, especially strong from France, Italy, and more recently Croatia.

Aquaculture is another sector that would broadly benefit from the application of marine biotechnologies that aim at improving breeding; minimizing and controlling diseases and optimizing the cultivation process. From a quick check of 2010 FAO data, it appears that Tunisia aquaculture sector is very promising, with active international trade, even though not completely developed. Therefore, the already existing stream of research that focuses on optimizing the inland and marine fish and shellfish cultivation methods might benefit the sector, improving the tradability/competitiveness of the products. In addition, aquaculture practices, reducing fishery, can improve the environmental status of the natural stock of marine resources (fish and shellfish).

Finally, we have empirically shown that Tunisian researchers are extremely productive and determinant for the generation of high technology products. The third policy suggestion refers to designing "attraction" policies that avoid "brain drain", since skilled labour is fundamental to the research and biotechnology sector. It is very interesting to signal that international companies and

research agencies already invest in Tunisia researchers, thereby acknowledging their professional, international competitiveness.

Table 2 summarizes our discussion, suggesting some (qualitative) non exhaustive list of costs and benefits of the three suggested policies in the field of blue biotechnologies and economic sectors (with a view to sustainable economic development) in Tunisia. In particular, we have to compute the costs of feasible reconversion between different sectors (for instance from fishery to aquaculture); the opportunity costs of Tunisian researchers to in their country and compare those figures with the computed benefits obtained by the implementation of suggested strategies and policies.

Table 2: Costs and Benefits of Sustainable Economic Development Selected Policies

Suggested Policy	Benefits	Costs
Encourage Marine Biotechnologies applied to Thermal Tourism	<ol style="list-style-type: none"> 1. Cosmetics (e.g. algae) and health research is already going on in Tunisia 2. Increase competitiveness in the Mediterranean Sea, by segmenting a peculiar market niche 	<ol style="list-style-type: none"> 1. Costs of the biotechnology research 2. Investment in the formation of ad hoc workers (e.g. beauty, health and fitness experts); costs of hiring the experts <p>.....</p>
Encourage Marine Biotechnologies applied to Aquaculture	<ol style="list-style-type: none"> 1. Applied to aquaculture research is already going on in Tunisia 2. Help developing a promising, though not well developed market; 3. Decrease fishery, so that to minimize the depletion of the fish/shellfish stock 4. Generate positive spill over with tourism (mostly restaurants sector, being less dependent on weather conditions in the food supply to customers) <p>....</p>	<ol style="list-style-type: none"> 1. Costs of the biotechnology research 2. Switching (economic and social) costs of sector restructuring (e.g. from fishery to aquaculture) <p>....</p>
Avoid Tunisian Researcher “brain drain”	<ol style="list-style-type: none"> 1. High productivity of very skilled workers remain favours the country 2. Increased probability to achieve publishable and patentable scientific results 	<ol style="list-style-type: none"> 1. Costs of offering international competitive wages to national researchers

A final caveat is due. It refers to the scientific requirement to deepen the final, qualitative conclusions with solid and rigorous empirical research that compute economic costs and benefits of the suggested measures. Only when we have reliable figures (obtained with the application of state-of-the-art market economic valuation methods) , will we be able to draw credible conclusions on suggested policy actions.

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7. Verbeek M. (2002) *A Guide to Modern Econometrics*, Wiley Editor.

Internet Links:

A.Socio Economic Data

1. <http://data.worldbank.org/country/tunisia>
2. <http://statistics.unwto.org/>
3. <http://whc.unesco.org>
4. <http://www.africaneconomicoutlook.org>
5. http://www.fao.org/fishery/countrysector/naso_tunisia/en

B. Information on Stakeholders, Policies and Actions

6. Ministère de l'Enseignement Supérieur (Ministry of Higher Education).
Web site : <http://www.mes.tn/technopole/>
7. Association Tunisienne de Biotechnologie (Tunisian Biotechnology Society)
Web site : www.atbiotech.rnrt.tn
8. Association Tunisienne pour l'Information Scientifique (ATIS)
Web site : www.atis-tn.org
9. Biotechnopole de Sidi Thabet
Web site: www.biotechpole.rnu.tn
10. Centre National des Sciences et Technologies Nucléaires
Web site: ww.cnstn.rnrt.tn
11. Institut National de Recherche et d'Analyse Physico-chimique
Web site: www.inrap.rnrt.tn
12. Institut Supérieur de Biotechnologie de Monastir
Web site: <http://www.isbm.rnu.tn/>
13. Centre de Biotechnologie de Sfax
Web site : www.cbs.rnrt.tn
14. Center of Biotechnology of Borj Cédria
Web site: biotech@cbbc.rnrt.tn
15. Centre technique de l'agriculture biologique (CTAB)
website : <http://www.ctab.nat.tn>
16. Institut National des Sciences Appliquées et de Technologie (INSAT)
Web site : <http://www.insat.rnu.tn>
17. Institut Pasteur de Tunis
Web site: <http://www.pasteur.tn>
18. The National Institute of Marine Science and Technology (INSTM)
Web site : www.instm.rnrt.tn/

C. Information on experiences/case studies

19. Institut de l'olivier de Sfax
Website : <http://www.iresa.agrinet.tn>
20. Ecole nationale d'ingénieurs de Sfax
Website : <http://www.enis.rnu.tn>
21. Réseau National des Pépinières d'Entreprises
Website : <http://www.tunisieindustrie.nat.tn/pepinieres/home.asp>
22. Pépinière Mabrouka
Web site : <http://www.tunisieindustrie.nat.tn/pepinieres/home.asp>

Technical Appendix

We test the following log-linear empirical model:

$$(1) \text{ Log High Technology Export}_{i,t} = \alpha_{i,t} + \beta \text{LogGDP}_{i,t} + \beta \text{LogR\&Dresearchers}_{i,t} + \beta \text{Logtechnicians}_{i,t} + \beta \text{LogR\&DExpenditures}_{i,t} + \varepsilon_{i,t}$$

where the dependent variable is the logarithm of the high technology exports, measured in monetary terms; the explanatory variables are the logarithm of the GDP, the logarithms of the numbers of researchers and technicians in R&D, the logarithms of the expenditures in R&D in monetary terms (U.S. current dollars) for the i th observations in t periods (1998-2006) The model contains a constant and an error term and was estimated by the ordinary least squares (OLS) method. Results are presented in Table 1.

Table.1: Tunisia High Technology Exports

<i>Variables</i>	<i>Coefficient Estimate</i>	<i>P-Value</i>
<u>Dependent Variable</u>		
(Log)High Technology Exports		
<u>Explanatory Variables</u>		
LogGDP	0.129	0.025
LogR&Dexpenditures	0.850	0.005
LogR&D_researchers	1.781	0.000
LogR&D_technicians	0.003	0.640
Constant	10.805	0.014
"R-squared"	0.85	

Statistical diagnostics shows that the goodness of fit indicator (R-squared whose value can span from 0 to 100%) is 85%. This means that the empirical model well captures the hypothesized relationships among variables and that our hypothesis is therefore reasonably confirmed. The p-values show the statistical significance of estimated coefficients. With the exception of the LogR&D_technicians variable (representing the number of technicians working in the R&D sector), all p-values are below 5%, indicating, therefore that the estimate is correct. We can, therefore, interpret with credibility the estimates and the empirical results.