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Turkish biotech

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Abstract
The paper examines the internationalization of an innovation system theoretically and empirically. By doing so, it expands the national innovation systems literature by integrating internationalization into the theory and further presenting the perspective of developing countries. Based on mapping innovation processes/functions over time, it becomes possible to develop insights in the dynamics of innovation systems. This mapping is carried out for the Turkish biotechnology system and the findings are summarized.

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FUNCTIONALITY OF THE TURKISH BIOTECHNOLOGY SYSTEM

1 INTRODUCTION

Without doubt, developing countries having capabilities for creation and use of biotechnological products and services may increase their competitiveness and help bring welfare to their societies. The question is, however, how these countries can go about to develop and implement such a critical capability, given a catch-up situation where highly industrialized countries may have a much more advanced situation.

The literature tells us that each country's innovation system (IS) for biotechnology must be well functioning in terms of dynamics, flexibility and resilience (OECD, 2009). The dynamics of the IS can, for example, be analyzed by the aid of functional approach (Bergek et al., 2008), which helps to highlight the most important processes that need to take place in the IS to lead successfully development and diffusion of innovations (Hekkert et al., 2007).

First, while many studies have attempted to understand how nations have tackled the creation and development of systems where new technologies are embedded (Niosi and Bellon, 1994), the majority of these studies are concentrated on advanced countries, furthering the framework as specifically related to the problems and priorities of such countries. There is however a relative lack of understanding how an IS can handle catch-up in an advanced technological area (Niosi et al., 2012; Mytelka, 2004; Niosi and Reid, 2006). This has led to less focus on the specific challenges faced by many developing countries

Second, in a global knowledge economy a national IS needs to be high connected to other global nodes, having frequent and high-qualitative knowledge flows (Pavitt and Patel, 1999; Gertler and Levitte, 2005). We may call this *internationalization* of the IS. However, as Carlsson (2006) highlights, only a few studies explicitly examine the internationalization of ISs theoretically, and even a lesser number of studies give empirical observations of internationalization at the system level (Niosi and Bellon, 1994; Bartholomew, 1997).

This paper aims to discuss catch-up possibilities of ISs in developing countries, addressing specifically the void in the two dimensions mentioned above – specifics of developing countries and internationalization. We do this through a study of the performance and internationalization of the Turkish biotechnology system. The paper contributes to the functional approach to IS dynamics, by pointing out specific conditions for developing countries. Analytically, our contribution lies in the realm of operationalizing internationalization of IS. Furthermore, the two key empirical questions the study aims to investigate are the performance of the Turkish biotechnology system (with a special focus on the internationalization dimension), and to identify barriers and enablers to its performance, so that policy makers can be equipped with a broad perspective that will help to improve the performance.

2 CHALLENGES OF CATCH-UP AND DYNAMICS

2.1 UNDERSTANDING INNOVATION SYSTEMS FOR CATCH-UP

As mentioned above, a large body of literature within the IS sphere focus on highly industrialized nations, perhaps leaving out issues that might be essential to developing countries. There are however some notable exceptions of IS research – for example, Mytelka, 2004; Jacobbsson and Bergek 2006, Niosi and Reid, 2007; and Lundvall et al. 2009, – focusing specifically on the needs of countries in catch-up situations. These contributions draw attention to some specific concerns for developing countries.

One specific point is that many studies focus on state-of-the-art innovations and new wave technologies/high technologies. While such technological domains may be of importance also for developing countries they may be so in different ways, and current literature may not always offer guidelines for the growth concerns of developing countries. One group of scholars believes that investing in new technologies will pay off also for developing countries in the long term, for example as described by Kim (1997) related to the successful Korean experience. However, 'over-reliance' on new technologies for growth might bear many problems. Low tech sectors may be as innovation dependent as high tech. Also, even in developed economies “the relationships between high tech and low tech sectors are highly symbiotic and the health of high tech firms and industries depends heavily on their ability to sell their outputs to other sectors” (Robertson and Patel, 2007, p. x). If this is the case for advanced countries, it is even more so for developing countries that have a limited number of high tech firms and industries, if any.

Another issue is that it may not be the exploration per se but the exploitation and utilization of a wide variety of technologies that makes a difference (Lall, 2000), where the process of adopting a technology and using it in a new context may incorporate many small innovations in different dimensions. In short, the majority of developing countries might generate more value for their economic and social growth from already available technologies but only if they could find ways of managing/exploiting them, by transforming their existing industries, by building new industries, or by simply running them more effectively

Another pertinent issue is that of internationalization of the IS. In a catch-up situation one must make wise choices of what actors and functions that are necessary to have within the national borders, and which can be connected to globally. In practice then such international connections implies understanding, and implementing, the various ways actors and processes can be internationally linked to foreign actors and systems?

2.2 DYNAMICS OF GLOBAL INNOVATION SYSTEMS

The concept of innovation system is a useful heuristic framework to understand structure and dynamics of innovation processes. In general, innovation systems (IS) can be seen as socio-technical systems where the comprising structural elements - knowledge and artifacts, actors, networks and institutions – all come together to support and enhance innovation processes. Innovation here refers to something much broader that invention, and implies development, market introduction, diffusion and use of services, products, processes, or organizational solutions new to the world or to a sector. In essence, the underlying theoretical foundation being evolutionary economics, the concept of IS aims to capture the complexity of innovation processes in terms of the whole as well as the interrelationships and interaction between the elements constituting the whole. This type of analytical framework has been developed with various units of analysis in mind: national innovation systems (NIS), regional (RIS), sectoral (SIS) or technological (TS or TIS) (Carlsson and Stankiewicz 1991; Lundvall 1992; Nelson 1993; Carlsson and Stankiewicz 1995; Asheim and Isaksen 2002; Asheim et al. 2003; Carlsson et al. 2002).

However, as Hekkert et al. (2007) and Laestadius and Rickne (2012) suggest the family of concepts – and often also their implementation in various empirical studies - suffer some flaws. We want to here point out how we think these can be redeemed, and how we will approach them in this study.

First, the IS concepts all assume that innovation processes are global and that the geographical delineation of a specific studied system (NIS, RIS, SIS, TIS) simply denotes a part of that global system. In order to understand the entire IS one would thus need to simultaneously look at many or all such geographically delineated parts of the global system. This, no doubt, becomes a daunting task and has never or rarely been attempted, even though several comparative studies of IS in various regions and countries exist (e.g. Cooke, 2006; Lundvall et al., 2009; Edquist and Hommen, 2010). In essence, analysts still lack tools to fully incorporate global process into IS studies. Therefore, a pragmatic incorporation of the international dimension of the dynamics of any innovation system often has to focus on some aspects of internationalization. It may involve analysis of, for example, international knowledge networks, the role of foreign recruitment for resource mobilization or how regulations in other countries affect the IS.

Another aspect of the global dimension is to what extent a full system should be present on the regional or national level. In essence, there is no intrinsic value to having all type of actors and functions on the regional or national level, as long as they are present in the system as a whole, and the regional/national system can benefit from these. For example, a foreign venture capital market may be sufficient to spur entrepreneurial activities or engineers educated in another country may be attracted to the region thus rendering own educational efforts obsolete. Therefore, internationalization of an IS - meaning that some actors and functions are handled outside the national boundaries - may very well be a way to enhance the functionality of ones own system. Especially this may be true for countries in a catch-up situation, as discussed in the next section.

Second, while its foundation may be evolutionary, the methods of analysis and practical implementation have sometimes tended to become rather static in nature. To tackle this, researchers have proposed a number of key processes - or *functions* - necessary for the progress of an IS (Rickne 2000, Bergek 2002; Jacobsson and Bergek 2006, Hekkert et al. 2007; Bergek et al. 2008a). By focusing on the most important processes that need to take place in innovation systems to lead successfully to innovation development and diffusion, these authors want to move the research frontier towards analysis of dynamic, evolutionary mechanisms. Table 1 presents a list of such functions – key processes - which by definition are to be seen as mutually interdependent and overlapping, but nevertheless serve as a good gauge to the dynamics of the system.

Table 1: Key processes in an innovation systems

Key process/Function	Description
Knowledge development and diffusion	The generation of breadth and depth of the knowledge base of the IS, and the diffusion and combination of knowledge, taking into account different types of knowledge (technology, design, market, etc.).
Influence on the direction of search	The existence of incentives and/or pressures for actors to enter the IS, and to direct their activities towards certain parts within the IS.
Entrepreneurial experimentation	The probing into new technologies and applications in an entrepreneurial manner.
Market formation	The articulation of demand, the existence of standards, and the timing, size and type of markets actually formed.
Legitimation	The social acceptance and compliance with relevant institutions.
Resource mobilization	The extent to which the IS is able to mobilize competence (human capital), financial capital and other relevant resources.
Development of positive externalities	The generation of positive external economies, such as pooled labor, knowledge spillovers, specialized intermediate goods, and complementary products, services and infrastructure.

Source: Development of Bergek *et al.* 2008a: 414-419.

2.3 A FUNCTİONALİTY APPROACH FOR DEVELOPİNG COUNTRİES

In this section we bring together the aspects discussed above into an analytical approach that addresses dynamics of biotechnology innovation systems in developing countries.

Knowledge development and diffusion

Generation and diffusion of new knowledge is a key element in emerging areas like biotechnology. In general, this may involve various types of knowledge – scientific, technological, on processes, services, markets, design, distribution, etc. – but our focus here will be merely on scientific and technological knowledge. A main body of knowledge in a biotechnology system is the strong scientific capacities of both firms and academia. In developing countries, knowledge is to a large extent generated in universities and government-owned organizations. However, there are concerns about the efficiency of transfer of knowledge from universities to industry in these countries. This is even a complaint in many advanced countries in Europe, linking to incentives such as framework programs in order enforce collaboration and overcome the problem. As regards diffusion, networks might serve a different purpose for emerging economies by compensating the latter for their undeveloped external markets for product development, financial capital, and entrepreneurial and management know-how (Melon et al., 2009; Niosi and Reid, 2006). By drawing on networks, developing countries could tap into knowledge created anywhere in the world and thus become internationalized (Carlsson and Cetindamar, 2003).

Legitimation and the influence of the direction of search

The creation of legitimacy – or the counteracting of resistance to change - refers to social acceptance and compliance with relevant institutions. The new technology and its proponents (researchers, firms, etc.) need to be considered appropriate and desirable by relevant actors in order for resources to be mobilized, for demand to form and for actors in the new innovation system to acquire political strength (Bergek et al., 2008). Standard setting and regulatory frameworks are prime examples of how firms are supported not only in knowledge development but also in their legitimation process in the national and global market.

The legitimacy problem in Europe has been a large hindrance for the development of biotechnology. Activities of political parties and many civil society organizations put pressure on companies dealing with biotechnology. A similar concern might be relevant for developing countries where low levels of education would certainly necessitate clear explanations about the technology and its implications.

Guidance refers to the combined strength of factors influencing the search and investment behavior of actors in the innovation system. This might include sufficient incentives and/or pressures for them to undertake investments, and may involve regulations, laws, dominant firms' strategies, public debate, availability of research funding for certain development tracks, market incentives for specific product development, etc. We are here in specifically interested in what influences the direction of research endeavors. While these may be guided by a multitude of factors, in this context it is important to point out that developing countries need to take charge over the direction of their own biotechnology research and production due to three major reasons. First, they need to solve their own unique problems; otherwise the development of biotechnology in industrialized countries alone may follow different paths and may not solve developing countries' problems. Second, there is a threat of substitution products. It is known that industrialized countries have started to produce some products in their laboratories such as sugar-substitutes. Finally, developing countries cannot benefit and influence the international research programs where they cooperate with industrialized countries. Many studies have shown that the researchers of industrialized countries mostly determine these programs (Sharp, 1996; OECD, 2009).

Entrepreneurial experimentation

The idea of entrepreneurial experimentation denotes the exploration into new knowledge areas and applications in an entrepreneurial manner. Taking an evolutionary standpoint, many and diverse experiments by various actors and in different areas gives the foundation for an innovation economy. Only in an experimenting economy will new combinations – innovations – be detected and lead to selection of these for further development. This means that experimentation needs to be ongoing in various part of the system: at universities and research institutes, in firms, in financing organizations, in customer settings, in policy organizations, etc. These experiments should be entrepreneurial in character, implying the eye towards innovation and associated market introduction.

It is widely documented that the R&D activities of multinational companies are being increasingly internationalized (as measured, for example, by the proportion of industry R&D expenditures financed from foreign sources, the number of international alliances, etc.) (Ramamurti and Singh, 2009). Therefore, and especially important to developing countries, entrepreneurial experimentation might be carried out with multinational companies. However a word of caution is necessary. As some research show, multinational firms prefer to keep their key R&D activities in their home country so their location in host a country might not necessarily bring the state-of-the-art technology to that setting (Khanna and Palepu, 2010). Developing countries could attract foreign R&D only with a clear policy vision backed with strong infrastructure. Some countries have built their development strategy on learning from the leaders in specific targeted areas such as biotechnology (Yeah, 2008).

Market formation

For any innovation system to function well there must be mechanisms for forming markets. These markets may be national or global, where the important point is that the actors in a specific IS must gain access to existing markets, or have means to create new ones. Issues often considered here are the role of domestic lead users, national procurement schemes and the transition from nursing to mass markets.

Of particular relevance to our study is that new technologies often have difficulties to compete with embedded technologies, since most inventions are relatively crude and inefficient at the time when they are first recognized as constituting a new innovation. Thus, diffusion under these circumstances will necessarily be slow (Sharp, 1996). An OECD report (2009) draws attention to this hindrance for biotechnology: complex scientific challenges and poorly designed regulations could reduce the ability of industrial biotechnologies to compete with other alternatives.

Because of this, it is often important to create protected spaces for new technologies. Some mechanisms of dealing with this might be the formation of temporary niche markets for specific applications of a technology or the creation of a competitive advantage by favorable tax regimes or minimal consumption quotes for temporarily period of times. Government policies influence the development of markets in many ways. At the international level, it is important for developing countries to influence global standards and regulations that are mainly designed by industrialized countries. In particular, the increasing intellectual property rights and protection in industrialized countries in the area of biotechnology indicates that technology transfer will become difficult and in some cases impossible for developing countries. Thus, internationalization requires developing country policy makers to be active in global networks.

Resources mobilization

Resources of various kinds –financial, human capital, components, etc. - are necessary as a basic input to various activities within an innovation system. For any specific knowledge area or sector, the allocation of sufficient resources by government as well as by companies is indispensable to make knowledge production and innovation possible. Naturally, the resource environment will differ substantially between regions and countries. Some of this relates to mechanisms with strong inertia – such as the setup, profile and attractiveness of an educational system - while other resources are possible to create or reallocate in shorter time spans. Examples where private actors can induce increased resource supply include when a MNC move into a region bringing with it component suppliers, skilled people and possibilities for research collaborations. Other mechanisms are spurred by public actors, and may involve policies such as establishing technology funds dedicated to biotechnology firms or creating new research centers on biotechnology. This can guide both researchers and entrepreneurs/intrapreneurs in strengthening their commitment to biotechnology. Indeed, policies at the national level help establishing country-specific factors (such as the competitive climate, the financial system, and educational system) and have an influence in creating national technological advantage (Patel, 1997).

3 OUR APPROACH AND RESEARCH DESIGN

To ensure as encompassing empirical data as possible, our ambition for this study was to identify the complete population of Turkish biotech firms, and from this population sample firms to investigate. We aimed to identify dedicated biotech firms – i.e. firms 'whose predominant activity involves the application of biotechnology techniques to produce goods or services and/or the performance of biotechnology R&D' (OECD, 2005) – but also companies having biotech-related activities as part of their production and research activities.

The starting point in identifying Turkish biotech firms was two previous studies conducted in Turkey, identifying a population of 50 and 90 biotechnology-related firms, respectively (Basaga and Cetindamar, 2001 and 2006). We updated these firm populations studies in 2010, with the same methodology of referring to industry associations, reports and newspapers, company listings and firms' web pages. Each source was carefully scrutinized to verify the firms' biotech activities. For example, in the Biotechnology Association's database not all companies are active within the biotechnology field. All in all, we identified 120 active firms, and 20 additional firms that had closed operations.

Our sampling strategy was to acquire a representative sample of the total population by including a balanced theoretical sample based on sector, size, age, and firm location. The resulting sample consists of 46 active firms (38% of the population), and 4 firms (20%) that had closed operations. Our aim was to mainly discuss with the dedicated biotech firms, so only five of the sampled companies are not directly "dedicated biotechnology" firms, in other words have minor biotechnology activities today but they might have potential to invest in the field in the future (OECD, 2009). For example, one of these is an agricultural firm with 1,550 employees of whom only 30 are working in biotechnology and where biotechnology is mainly used for test purposes.

In addition, we conducted interviews with other actors in the innovation system: five academicians and five managers in government agencies. These interviews allow triangulating the firm-based data, and for further observing the dynamics of the innovation system.

The study measures the system functions by the variables presented in Table 2, clustering them in a somewhat different way as compared to Bergek et al. (2008). In order to capture these variables a combination of quantitative and qualitative data was collected. As the main source for understanding functionality, interviews were conducted with the CEOs of the 50 companies in the second half of 2010.

Table 2 Functions focused in the study

Development and diffusion of scientific and technological knowledge

Legitimation and Influence of the direction of search

Entrepreneurial experimentation

Market formation

Financial resource mobilization

As regards development and diffusion of scientific and technological knowledge we have focused on scientific and technological knowledge in this analysis. First we describe the actor setup and measure the volume of university and institute research in terms of number of units and employees. This gives an overall understanding as to whether biotech is a focused field in Turkey. Furthermore, we used two common indicators to map output: a), b) research output in terms of publications, c) output in terms of patents. We also discuss sectoral focus of the research and technology development, and the involvement of foreign actors. Finally, the structure for knowledge diffusion was mapped, and interviewees were asked about their perception about how knowledge generation and diffusion works.

Legitimation is discussed in terms of public debate and interest groups. We also analyze the role of Turkish policy in influencing the direction of search, and let interviewees reflect on their view on actors or events guiding the field. As regards *entrepreneurial experimentation* we start this analysis by an overview of the firm population. This leads to discussion of experimentation in general and about firm entrepreneurship.

The function of 'market formation' is analyzed by mapping the size of user markets, and some development trends as given by e.g. firm respondents. Pertaining to resource mobilization we focus specifically on financial resources. We measure financial resources in terms of funds made available for long term R&D programs set up by industry or government to develop specific technological knowledge, and public and private funds made available to e.g. allow testing of new technologies in niche experiments. Besides available quantitative data, interviews help to observe perception of innovation actors about financial resources.

4 SYSTEM FUNCTIONALITY AND THE ROLE OF INTERNATIONALIZATION

4.1 DEVELOPMENT AND DIFFUSION OF SCIENTIFIC AND TECHNOLOGICAL KNOWLEDGE

There are 137 research units active in the biotechnology field, as hosted in 71 faculty research organizations and 4 research institutes. As regards research output from universities and institutes, publications have increased, but from a very low starting point. Patenting of research activities is very low indeed, where the average number of patents per researcher at a university or a research institute was 0.003 in 2004 (TÜBA, 2004). Firms' patenting this figure is also low due to costs of patents and limited benefits.

Interestingly, even though the Turkish economy is dependent on agriculture – where 20% of GDP comes from agriculture and 35% of employment is within that sector – more than half (56%) of the publications are in the field of health biotechnology, while less than one fifth deals with agriculture.

The patent data gives opportunities to scrutinize patterns of international connections. First, the total number of biotech patents in Turkey (including universities, institutes, firms, etc.) adds up to 208, out of which only 53 are issued by Turkish inventors while the rest belongs to foreign firms operating in Turkey. Clearly, due to market growth, foreign firms are increasing their investments in Turkey and hence they patent their technologies to protect them in the local market. Second, the national to foreign patent ratio indicates that national patent levels seem to stay the same while foreign applications are increasing. The foreign patent applications in 2000 were 624, but had increased to 985 in 2005 (Basaga and Cetindamar, 2006). Third, when Turkish researchers are the inventors they are not necessary the assignees of the patents. In the US patent database the patents with Turkish inventors a third of the assignees are foreign firms from Italy, Germany, UK, Slovekia, and the US.

Our next issue relates to the structure for knowledge diffusion. A mapping of the relevant networks, and as based on our interviews shows that Turkey, like other developing countries, faces a problem of low connectivity, preventing them from utilizing even the existing technological changes due to the failure of diffusion mechanisms (Niosi et al., 2012).

4.2 LEGITIMATION AND THE INFLUENCE OF THE DIRECTION OF SEARCH

To gain legitimation for the application of biotechnology in various sub-sectors there needs to be a general public trust in the science, technologies and products (Aerni and Bernauer, 2006). Issues such as safety are crucial, as are discussions of societal benefits, intellectual property rights, and ethics. In particular, in biotech the safety issue is crucial from the society's perspective and globally many social and political groups are actively involved in biotechnology related debates. In many European countries interest groups are well organized and influence political mechanisms.

In terms of intellectual property rights, even though patents were not traditionally used to protect living organisms, recently there has been an increasing tendency in industrialized countries to provide patent protection to biotechnology-based innovations. Therefore, many international organizations, attempt to deal with the problems of accessing and controlling plant genetic resources and living organisms at the international level. While Turkey adheres to general agreements, the problem is the application of laws and their enforcement in daily practices. Government policy organizations are important to set the agenda for how actors perceive the investment and growth opportunities in a specific field.

The developments in the last eight years indicate that - except in a few cases - planned actions were not realized. In fact, in numerous meetings, biotechnology has been given high priority but most of the decisions taken have not been operationalized, due to the lack of political commitment by governing parties. In essence thus: Even though Turkish policy makers have identified biotechnology as a critical technology, available regulations do not support this. To us is seems obvious that Turkish policy for biotechnology does not give clear or long-term support for the field. This is a major hurdle to the development of the area as such.

There are of course possibilities of other actors taking on the role of guiding the field. For example, in many countries and sectors large firm strategies lead to followers in both academia and industry, and create legitimacy on the market. Such actors are not present in Turkey, at this point. Instead, firms are left to observe and adhere to international trends, visions and regulatory stances. Only a few firms manage to establish strong links with international actors. In the future, these firms might generate enough critical mass for others to build a strong network of companies that can guide biotechnology policies.

4.3 ENTREPRENEURIAL EXPERIMENTATION

Experimentation – on science, technology, business model, usage, policy support, etc. - is crucial in that this gives the possibility for variety creation and successful implementation on a market. One obvious way to gauge experimentation is by the *volume* and *variety* of actors present. The number of biotechnology firms identified in Turkey increased from 50 to 90 to 120, for the years 1999, 2005 and 2010 respectively. While it is difficult to gauge what is a sufficient firm population, we can compare with other countries where Turkey has 1,6 companies per million inhabitants, whereas, for example, for Finland the corresponding figure is 28,2, in South Korea it is 15,8 and in Brazil it is 1,2 (OECD, 2009; CEBRAP, 2011). While it is positive in terms of the number of ongoing experiments that the firm population is growing, it seems clear that the number of biotech firms in Turkey is still too small to give a critical mass and generate positive synergies and spillovers, which could eventually set the foundations for an innovation-driven growth industry.

Another way to create impact then – and give opportunities for experimentation – is that the firms grow in size. In terms of employment figures, the development is not that impressive. Even though a few firms employ around 500, the majority of firms have less than 50 employees. The growth patterns seem to be steady, albeit with a few exceptions.

Out of the total set of 120 companies in 2010, 95 had own development and/or products, while 25 firms are service firms selling international products in Turkey so they have no production and R&D in the country. Interestingly, the proportion of dedicated biotech firms (DBF) has grown, with approximately 8 firms in 1999, 24 in 2005 and 50 firms in 2010.

Some concerns have risen by interviewees in relation to how policy might affect firm development. For example, when a manufacturer imports raw materials, they pay 18% tax, however the imported products are taxed with only 8%, thus the local producers are penalized with the burden of additional tax (10%) (TOBB, 2009). Also, given the fact that 71% of the health sector services are not directly paid by customers but by government, it is troublesome when government pays with long delays. This is particularly a critical problem for innovative small firms that have limited financial sources. In fact, interviewed managers of two firms that were out of business indicated this as the most important problem. In addition, foreign firms raise concerns about copyright piracy, trademark counterfeiting, and IPR enforcement (WPR, 2010). One company ordered a machinery to be produced by an outsider supplier in order to use in its unique production, the machinery's patent belonged to the biotech firm. However the supplier used the know-how to produce the machine for the competitors' of the biotech firm. The patent owner sued the supplier but they could not get any result yet even though it has been three years. Small and innovative firms cannot survive so long under such uncompetitive conditions.

It is often positive for experimentation that there are several types of firms in the industrial set-up. As related to sectors, 75% of the companies are active within the health sector (medical and pharmaceuticals). This corresponds well with research profiles at domestic universities and institutes, where the main focus of biotechnology research is health sciences. Accordingly, only a few firms concentrate on agricultural applications which take around 9% of research funds in total of biotech research activities. There has been long tradition of research in agriculture however they are concentrated in traditional technologies and application rather than biotechnology and basic science.

Clearly, the dominant group within the Turkish biotechnology system is medical device companies (55% in 2010) as shown in Table 3. Even though, there are more than 3000 Turkish production firms in the medical industry with products ranging from hospital-textiles to wheelchairs, foreign companies dominate 90% of the medical market. So, these 50 small medical device companies are exceptional in terms of their head to head competition with foreign companies in a high tech field. These dedicated biotechnology firms produce products such as diagnostic kits and implants. The largest DBF employs more than 40 people (while the majority of firms employ less than 10). Also, 12 out of the 15 spin-off companies from academia are medical firm, and the dynamism of entrepreneurship seems to lie in the medical device sub-sector. This is also the most internationally connected sub-sector, as all firms having international research connections are medical firms. Two main historical reasons for the strength of medical device companies compared to pharma firms are: the ease of entry to the sector with low investment requirements and simple regulations for medical products.

Table 3. Distribution of firms according to sectors (1999, 2005, and 2010)

User market	***1999***	***2005***	***2010***
Medical devices	26	37	66
Pharmaceutical	6	14	24
Agriculture	6	8	8
Chemical	5	7	7
Food	6	9	6
Environment		7	5
Energy	1	8	4
Total	50	90	120

Source: Basaga and Cetindamar, 2000 and 2006. Data for 2010 is the authors' own data collection.

As shown in Table 3, 24 Turkish pharmaceutical companies have biotech activities in 2010. Overall, a total over 300 pharmaceutical companies exist in Turkey, but 43 of them have manufacturing facilities, 14 of which are run by multinationals with no R&D operations (TOBB, 2008). An important discussion is therefore which of the pharma companies that may move into biotechnology. One such mechanism may be through foreign ownership, where there is a recent trend of acquisitions of local firms by multinational firms in the pharmaceutical industry (WPM, 2010). While we do not have any evidence of such emerging biotech activities it is something to keep an outlook for.

As in the majority of developing countries a main part of industrial activity takes place in agriculture. Only a minority of the Turkish agricultural firms are however involved in biotech, since they are simply vegetable and fruit producers. There are likewise few biotechnology applications in the Turkish food industry. However, even though biotechnology offers many opportunities to increase the functional qualities of food (e.g. higher content of essential vitamins and trace elements, increased shelf life, etc.), the Turkish food producers are not investing in biotechnology applications in-house. This is because the majority of them are small-scale firms and not capable of investing in new technologies, only 7% of them have invested in automation-based production (DPT, 2004). In turn, large-scale firms that use biotechnology prefer to import biotechnology-based ingredients, such as starter cultures, rather than to produce them in-house due to cost concerns. Large multinationals have cost advantage in culture production arising from economies of scale.

This internationalization dimension of sales is of particular interest. Indeed, where even though born-global type of biotechnology firms is abundant in advanced countries, the internationalization in Turkey is for the most part limited to export-import activities. The majority of our sample - 72% or 33 firms - has international trade in terms of export-import activities. Interestingly, firms trade with diverse set of countries; only three firms concentrate on selling to developing countries and six firms sell to advanced countries alone, while the majority of companies have a wide range of countries in their portfolio with no concentration on developing or developed countries. Most companies manage their sales from a Turkish base, but 15% of the firms (7) have sales offices in a limited number of countries. In contrast, only 13% of the firms (6 firms) aim to get involved in international networks and develop integrative research-production processes at the global level, where two have research activities with international partners through formal agreements. Even so, there are however some examples of moves towards internationalization, where some activities are conducted through partnerships.

As regards firm origin, out of 120 Turkish firms in 2010, 15 have their origin at a university. While the volume and role of academic spinouts differ between countries and sectors and it is difficult to judge what is a preferable level, we can compare, e.g., with a population of life science firms in Western Sweden where a third of the population originated in university settings (Laage-Hellman and Rickne, 2009). This may indicate that there is a larger potential for reaping commercial results from academic research in the form of new firm formation. One argument would be that otherwise the restricted resources of developing countries may be spent for basic science that in turn may be transferred to foreign countries instead of benefitting to the local economy. However, special incentives and mechanisms may need to be created in order to stimulate the links between universities and industry. For example, in recent years the Turkish government changed the rules for involvement of academicians in technology parks and for having the right of their inventions, and this may be a good start.

4.4 MARKET FORMATION

The size of the Turkish user markets where biotechnology products are employed shows that the modest growth scenario foreseen by Basaga and Cetindamar (2000) has been realized, totaling a market size of US$1.77 billion in 2010. Among the sub-markets, health and food industries stand out as the drivers in terms of generating new companies. However, the majority of food companies are traditional products such as cheese, wine and beer where modern biotech research is only a limited activity if any. The only exception is the yeast producers, where the main one – the third largest producer in the world - has a modern biotechnology laboratory with almost 30 scientists. Adding imports, the total market size in Turkey increases to US$ 3.3 billion. This includes around US$ 0.3 billion worth of bio enzymes, US$0.8 billion biogeneric drugs, and almost US$0.4 billion bio-based health products (both pharmaceuticals and medical equipment) are imported and used in Turkey in 2010.

Table 2. Biotechnology user markets in Turkey (Million USD)

Sector	**1999**	**2010**
Health	350	700*
Agriculture	0	0**
Food	450	800
Chemical	30	60
Environment & energy	100	185
Others	0	10
Total	**930**	**1755**

* Medical market only.
** A potential market size of 700 Million USD could be reached if biotechnology applications had been allowed in agriculture.
Source: Basaga and Cetindamar, 2000 and updated data by the author (For details see Appendix A)

The market is thus not impressive, and market formation mechanisms need to be enhanced in Turkey. As discussed above, medical firms is the largest group of biotech related companies, and they are in general the more dynamic ones in Turkey in terms of internationalization of their research and in conducting R&D with a reasonable number of patents. Therefore, it seems reasonable that a Turkish biotechnology strategy should involve efforts into health related applications, particularly in the medical equipment segment such as dental implants (TOBB, 2009). However, one hurdle to such a development seems to be government regulations in the health sector that delays the diffusion of new technologies.

Another regulatory constriction to market formation relates to that of agriculture. As Turkey aims to become a member of its main trading partner the EU, Turkish regulations must become compatible with EU regulation, but some perceive that the resulting regulatory adjustments are constraining the expansion of biotechnology into food and agriculture. EU has a preventive regulation of Genetically Modified Organisms (GMOs) (Aerni and Bernauer, 2006). Thus, one may say that Turkey has a potential for agriculture but it cannot realize it due to its dedication to the EU regulations. Agricultural biotechnology applications comprise tools such as tissue culture, genetic engineering and molecular marker breeding. While plant tissue culture and plant molecular marker breeding are applied to some extent in universities and research institutions, no research projects currently apply genetic engineering in plant breeding in Turkey. Genetically modified products are neither cultivated on Turkish soils, nor imported. The Ministry of Agriculture has allowed only a few test plantations of genetically modified seeds of cotton, corn and potatoes in 2004. The Turkish Scientific and Technological Research Council (TÜBİTAK) nevertheless predicts that biotechnology applications will become widely used and argues that Turkish agriculture, in particular, may benefit a lot from improved plant types, increased quality features and higher resistance to various environment conditions (i.e. drought) and disease (TÜBİTAK, 2004). However, there is no wide application of biotechnology in agriculture industry.

Another subsector of interest as regards market formation is that of environment and energy. While environmental concerns are roaring at the global level there is not much development in improving the water and solid waste treatment conditions in Turkey. Industrial waste accounts to 55% of the total waste but only 9% of it is treated, and only 11% of industrial establishments have waste treatment facilities in their plants (Enerji Bakanlığı, 2007). Also municipalities are lacking treatment facilities. Thus, even though the market is large for biotech based treatment solutions, the realization is yet a small amount and the biotech firms directed to environment market are few.

Even though there is a slowdown in many biotechnology applications due, for example, to the financial crisis, energy applications of biotechnology are increasing across the globe (Ernst&Young, 2010). Turkey is to a large extend depend on foreign energy sources, and in that context it is interesting that biomass is one option where biotechnology can be applied to improve plants and biological transformation systems for the production of fuels from biomass as in the case of Brazil (Quezada, 2006). In Turkey, biofuel makes up a mere share of 0.04% of the total national fuel consumption but this may increase to 30-40% if biofuel-promoting regulations in Europe could be adopted in Turkey (Enerji Bakanlığı, 2007). If this regulation change takes place, agricultural products will be transformed into biofuels and support the rise of energy-oriented biotech companies in Turkey. In the late 2000s there were around 300 firms working with biofuels but these firms have, with few exceptions, suspended their operations, the reason being that government raised the tax on biofuel so high that they could not compete with alternative products (Basaga and Cetindamar, 2000 and 2006). In essence then this means that there are today few companies focusing on biofuels, and even fewer that use biotechnology in their operations.

It seems clear that from the firm's perspective market formation is severely limited by governmental policy and regulation. Further issues related to market development concerns the role of users in innovation processes. The majority of developing countries do not have a substantial stock – or sometimes even any – highly skilled buyer firms (e.g., chemical or pharmaceutical companies) or end-users which may function as lead users. For example, the low education level of farmers makes successful application of biotechnology in agriculture difficult as they cannot comprehend and implement complicated biotechnology products. This lack of competence is coupled with the lack of effective demand, in turn preventing the build-up of critical mass to drive the development of biotechnology. Moreover, similar to buyer industries, the competence of supplier industries is weak. For example, one biotech company needed a transportation company to carry its goods at -50 ^{0}C, but it could not find any firm to satisfy the specifications.

4.5 Financial resource mobilization

As regards the distribution of loans and grants by government organizations for industrial research, the Turkish Technology Development Association (TTGV) invested in 240 technology projects during the period of 1991–2005. Within a total investment of US$95 million, biotechnology projects received 7.2% of the funds (Basaga and Cetindamar, 2006). An official R&D source for technology firms is TÜBİTAK-TEYDEB, which during the period of 1996–2004 granted US$219 million to 1303 projects, where biotechnology projects had a share of only 3% of the total. The neglect of biotechnology might be due to a number of reasons, bureaucracy being the most important reason. University researchers complain about the excessive documentation required by these agencies, and the complicated and long processes in receiving their required lab materials.

Even though a small portion of government funds are allocated to biotechnology firms, there are relatively strong R&D activities performed by biotechnology firms located in technoparks that have been initiated by government agencies since the second half of the 1990s. While Technoparks is recent phenomena in Turkey and there to date are relatively few involved firms, the figure merely shows a positive trend of high technology activities that may look encouraging for the biotech industry. In fact, 20% of the firms located in technoparks across different cities in Turkey have biotechnology activities.

It is no surprise that most of the developing countries' financial institutions are weak and venture capital firms are lacking. Another source for financial sources is international firms. In Turkey, a new R&D law was introduced in April 2008 in order to support both local and foreign companies that carry out R&D in Turkey. Tax incentives are offered including income tax exemption and stamp tax exemption.

5 CONCLUSIONS AND IMPLICATIONS

Clearly, systems of innovation are increasingly intertwined on regional, national, and international levels. Globalization does not undermine the role of the role of the region or nation, since international networks are developed on their base (Niosi and Bellon, 1994), but nevertheless the fact that various innovations systems are developed in parallel as nodes on the international map necessitates for regions and countries to connect to such nodes. Furthermore, the functions of any innovation system should be set in relation to the global processes, modifying the functions needed to be performed by the specific national innovation systems. Therefore, the actor set up, institutions and dynamics should be analyzed through an international lens. For example, innovation policies at the national level need to understand and connect to foreign and international policies in order to regulate and support international innovative activities. The uneven development of biotechnology system in different countries confirms that policies developed at NISs influence the overall success of biotechnology systems as well as their internationalization (Niosi et al., 2012).

This paper further tests the functional approach to the innovation system framework for a developing country. The paper has two major contributions: theoretically it integrates the internationalization perspective into IS and empirically it applies theory on biotechnology system in a developing country. Based on the key functions identified in the literature, this paper analyzes all functions by taking into consideration of internationalization activities and the concerns of developing countries. The goal is to understand not only the structure but also the dynamics of institutions and the interactions between actors of innovation systems that will result in successful technology exploration and exploitation activities.

Even though it has been indicated in 1994 by Niosi and Bellon, statistical indicators are not yet fully developed for both technology stocks and flows, from technological trade balances to market shares, and from national to international and regional comparisons. This is even more complicated for generic technologies such as biotechnology that has many applications in a wide variety of industries. The only reliable sources are Ernst & Young's special series on Biotechnology and The OECD's Directorate for Science Technology and Industry. However, most statistics are unable to seize the complexity of the innovation process and cannot allow delving into the processes of innovation systems. Therefore, the analysis of functions of innovation system might bring strong highlights about the mechanisms behind biotechnology systems. The future studies should first enrich this approach as this paper attempted to do by bringing internationalization dimension and then apply as many countries possible to bring data that can help for comparisons and benchmarking studies.

The analysis of Turkish biotechnology system helps to identify, understand and compare the crucial activities in biotechnology and it creates insight in the dynamics and possible patterns of technological change and related innovation processes as argued by Hekkert et al. (2007). The goal is to offer insights driven from the heuristic approach of functions that might guide and support actions of policy makers, managers and academicians who are the pillars of the innovation system. The overall analysis of structure and changes in the Turkish biotechnology system during the period of 2000-2010 indicates a lost decade for Turkey. The main assumption laid down in the 2000 report was “no change at all” (Basaga and Cetindamar, 2000). In other words, the expectations included: “the government will not have a specific policy with regard to biotechnology; government will not provide incentives to biotech producers; it will not prepare effective regulations; and it will not approve the use of biotechnology in agriculture” (ibid, p. 104). They are all realized and the share of biotechnology in total economy remained almost the same after the ten-year period.

Based on the functional analysis, the observation of the Turkish biotechnology system shows a relative growth in knowledge development though knowledge generated mainly in research institutes and universities with a weak tie with companies. There is some degree of entrepreneurial experimentation and market formation. However, two remaining functions are underprovided, namely the resource mobilization and legitimation & influence of the direction of research.

Overall, the Turkish biotechnology system is a small one in terms of firm activities, but even in such a context, all firms interviewed have some sort of international activities and even a few medical firms conduct a wide range of activities with their international partners. The analysis, however, shows that Turkish BT firms do not compete with their research and technologies at global markets. The most successful firms in internationalization are medical firms, and even they have either no or a few patents. So, the biotechnology system in Turkey is in its infant stage and benefits from exploitation of biotechnology in medical industry. There are also a few food producers who are operating in the traditional biotechnology but are successful in international markets. Foreign companies are not abounded, even though there are ones operating production in Turkey, but not those conducting research in the field of biotechnology.

In order to strengthen all functions in biotechnology system to generate a critical mass in Turkey, research organizations might focus on the strengthening of cooperation in biotechnology for many reasons. First of all, biotechnology is a multidisciplinary technology, integrating biochemistry, microbiology, bioprocessing, and chemical process technology. This integration of disciplines and skills is by no means easy to achieve, since it requires new forms of organization and structuring of firms and institutions. Second, biotechnology firms need to coordinate the management, R&D,

marketing, and distribution activities and become expert in all these dimensions. For example, Cuba and Brazil are the most important biotechnology producers in Latin America and the Caribbean, but still they lack world-class standards in process and product quality, and production engineering as well as marketing and distribution channels. Networks can bring not only capacity-building but also provide market access across a large number of industries through the channels of partners. Turkey like many developing countries should increase the connectivity not only among national firms and institutions, but also should gain expertise in increasing the efficiency of technology transfer at the global level. Developing countries may take advantage of joint-research ventures with either industrialized countries or other developing countries. For example, in Kenya, the Kenya Agricultural Research Institute and Monsanto Corporation from the US work together on virus resistant sweet potato variety by using Monsanto's genetic engineering technology. Similarly, Singapore established a joint-venture research institute (Institute of Molecular and Cellular Biology) together with Glaxo, the multinational pharmaceutical company. It seems the recent change in regulation for multinational firms in Turkey might bring inflow of global R&D in biotechnology.

In terms of firm lessons, biotech-related firms constitute a small segment of the Turkish economy, but given the growth expectations of the country and its crowded population, there is a potential growth for them that might start to build a critical mass. Admittedly, the firm base is small as of today, and many hinders for growth has been highlighted above. Even so, firms need to learn about the prospects and the evolution of biotechnology within the country and abroad to adjust their strategies. For example, government support announced for "Health Cities" and R&D incentives offered could provide a prospect for biotech firms to enter this field and develop competencies.

Implications for Policy Makers

Turkish government is a crucial actor in shaping the biotechnology system since two lacking functions are the resource mobilization and legitimation & influence of the direction of research.

In terms of directing the research, government policy needs to improve the receiver competence by deciding on the type of biotechnology industry that the national policies will target. Turkey like any developing country does not have the luxury of spending or risking its resources on dead ends. Thus, they may follow a few paths for biotechnology development. For Turkey a potential route may be to concentrate on building capabilities in well-established, proven and relatively simpler techniques in medical industry as the bulk of competence is already in this sector. The best example of this route is Brazil whose ethanol program relied on known fermentation technologies.

Whatever route of development and products is chosen for the Turkish biotechnology system, long-term, stable, and strong policies will be needed to build infrastructures for the supply of key resources. One infrastructure is needed to train scientific and technical manpower that will not only conduct research but perform high receptive capacity. Biotechnology applications are dependent on certain environmental conditions and need to be adapted to local conditions. That is why biotechnology necessitates an intensive adaptive research capability and continuous learning. This, in turn, increases the requirements for receptive competence of firms and researchers in developing countries. Considering that developing countries will need to import many biotechnology products, strengthening receptive competence becomes crucial for success. To do so, they need to be able to communicate with other scientists and exchange knowledge. But more importantly, the existing knowledge published in journals or available in databases needs to be exploited by establishing cooperation among researchers and firms that will facilitate international technology transfer into local economic activities.

Another critical resource is finance of new startup firms in biotechnology field and a stable infrastructure needs to be formed for long-term investments. The Turkish government may have created some funds to promote public-private sector collaboration and technoparks, but they are not enough to generate a critical mass with positive synergies in enterprise development. It seems the new technoparks generated a new stream of biotechnology companies across the country. However the interviews with some of these firms clearly show that as long as Turkish researchers cannot transfer their knowledge into products and services, the knowledge created will not generate any economic and social benefits. Even though there are good companies, and good researchers in these technopark companies, they are lacking critical competence about commercialization and can sometimes enhance the strategic visions. The starting support might be given to these already established firms to streamline their activities and concentrate on commercial products that will generate further resources for sustainable competitive advantage.

Technology policies should also include an internationalization dimension. Considering that innovation systems are based on learning, international networks might facilitate and speed up the process of learning in a new knowledge field. But more importantly, developing countries focus on exploitative technology applications so that they can turn their technology investments immediately into economic and social benefits. Hence, promoting international alliances, research networks, transfer of technology and foreign direct investment in biotechnology should be integrative parts of any technology policy. This policy was widely applied in Asian countries to direct biotechnology developments in their countries. Technoparks should be given special emphasis in the planned incentives in order to increase internationalization of dedicated biotech firms located in these parks that has higher potential for multiplier impact on economic returns.

In order to create awareness and acceptance of a new technology such as biotechnology, some legitimization efforts are needed. For example, having regulatory infrastructure including protection of intellectual property rights is one of the early steps in encouraging the development of local technologies and making use of the rich biodiversity in Turkey. In the social sphere, fear and prejudices might prevent long-term trust in technology. Thus, by educating young generations and letting them to experiment with a biotechnology toolkit, it becomes possible to create more interest among Turks in the advancement of science and technology. Government and civil society organizations might work together to exercise such a broad campaign.

In short, the potential advantages of biotechnology applications in Turkey can only be realized if all the actors of the biotechnology system (research organizations, firms, support organizations, policy makers, etc.) work together with a long-term strategy perspective (Cetindamar and Carlsson, 2003). It would enable Turkey to create its home-grown biotechnology capabilities and become better integrated in the global knowledge economy.

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