CHAPTER 6 CONCLUSION

6.1. Policy Implications

The concept of ***National Innovation Systems*** (NIS) highlights the importance of flows and linkages between firms and external sources of knowledge within a country. As the global economy evolves toward knowledge-based competition, it is imperative to build up an infrastructure for facilitating revolutionary innovation through knowledge fusion, bringing together players with very different disciplinary roots, objectives, expectations, traditions, and cultures to create new knowledge within an innovation system, regionally, nationally and internationally.

Traditional S&T policies emphasize providing public goods and subsidizing R&D to correct *market failures*. The NIS framework suggests that, governments should also address *systemic failures* that block the functioning of innovation systems, hinder the knowledge flow and technology diffusion, and consequently, reduce the overall efficiency of R&D efforts. Such *systemic failures* can emerge from mismatches between different components of an innovation system, such as conflicting incentives for market and non-market institutions (e.g. firms, research institutes, universities), or from institutional rigidities based on narrow specialization, asymmetric information, communication gaps, and lack of networking and mobility of personnel. Therefore, the government should carry out a more aggressively "diffusion-oriented" innovation policy.

6.2. Policy Suggestions

What follow are some suggestions for developing Taiwan's systems of biotechnology innovation, some of which might apply to other developing countries.

(1) Increasing Research Funding and Diversifying Funding Sources

Biotechnology heavily depends on basic research at universities and thus is highly science-based. So the key to developing biotechnology is the availability of leading-edge scientific capabilities. It is believed that the U.S. competitiveness in biotechnology is fed by substantial expenditures on basic research, which provides the life blood of national innovation system. Because of the long R&D process in biotechnology, and the enormous cost of laboratory equipment and materials, government support of basic research in the life sciences is a critical factor affecting a nation's stock of scientific knowledge related to biotechnology.

Increased funding, however, is only a part of the solution. Porter (1990) argued that investments in basic research, while important in seeding possibilities for commercial innovation, will not lead to competitive advantage unless transmitted to and further developed by industry.

Moreover, knowledge of public research is not freely available to all, but only to those who have the right educational background and to members of the scientific and technological networks. Therefore, firms also have to invest substantial resources in acquiring and using the research results, which rarely contains economically useful information.

(2) Encouraging Interdisciplinary Research Teamwork

Biotechnology includes a mixture of diverse disciplines and fuses separate streams of science and technology. This means that firms must have well-developed capabilities, which are the abilities to exploit knowledge across different scientific disciplines and industrial sectors, and to reach out collaboration among different types of firms and research institutes. That is, it emphasizes trans-disciplinary, where

disciplines merge in search of solutions to the problems in life sciences (for example, integrating academic activities, clinical research and medical practice into biomedicine).

(3) Strengthening Industry-University Relations

The formation and subsequent evolution of the network of R&D alliances between the academia and the industry can be interpreted primarily as an adaptive response to the emergence of a new knowledge base within the bio world, for example molecular biology. Therefore, efforts to promote research cooperation and interaction between industry and university have been one of the most constant and widely-supported elements of the U.S. S&T policy over the past three decades. It is believed that more intense cooperation between these two sectors will lead to a variety of benefits, including increased support for academic research, accelerated technology transfer, enhanced competitiveness, and ultimately economic development.

It is only recently that the government has setup mechanisms to help commercialize research results in Taiwan. Understanding the absence of the ties between the academia and the industrial sectors traditionally, different government agencies in Taiwan are independently experimenting with a variety of technology transfer mechanisms and building bio-clusters to facilitate collaboration between universities and industries at present. However, while the survey showed that many linkages between firms and research institutes are developing in Taiwan, it cannot be overemphasized that such institutional change would be a slow adaptive process. Norms of collaboration between the academia and the industry are not as well-established in Taiwan's innovation systems as they are in the advanced countries, and will therefore take much time and support before they take hold.

Besides, the problem of an inadequate supply of scientific research should also be addressed in Taiwan. At the moment, the supply of scientific research cannot meet the demand of industrial development. Therefore, the government should encourage a greater commercial orientation in the publicly-funded research institutions to facilitate the flow of knowledge between the academia and industry. The projects of the research institutions should be complementary to well-established companies, or have stronger links to "downstream" industries, such as pharmaceuticals and agriculture.

(4) Creating "Academic Entrepreneurs"

Universities and research institutes in Taiwan have great R&D experiences in agricultural biotechnology, but only few of their results have been commercialized yet. Therefore, it is important to promote of the creation of academic start-ups, spanning the gap between the research of the universities and the operations of the industries.

In Taiwan, unfortunately, the prevailing attitude in the academic community is that "pure" research is superior to "applied" research. Academic institutes have discouraged professors from being consultants to industry and only academic publications have been regarded as research outputs under the evaluation and promotion systems in universities. So there is a limited movement of professors between universities and firms. As a result, the phenomenon of "academic entrepreneurs" is nonexistent in Taiwan.

Taiwan government, therefore, should provide an incentive to professors to blend academic and industrial research in their careers, and try to reduce their "opportunity cost" (i.e., the potential loss of academic standing) of leaving the academia for the industry. For example, the evaluation and promotion systems in universities should

take scientists' contributions to industry in addition to academic publications, say patents granted and technology licensing, into consideration. And more importantly, university should encourage full professors to engage themselves in industrial consulting and in creating start-ups or spin-offs, and restore their academic standing and financial status once they return back to the university from the commercial world.

(5) Access to Global Innovative Networks

The evolution of biotechnology has taken place during an era of the advancement of information and communication technology (ICT), which has introduced an unprecedented level of international collaboration.

The openness of national innovation systems to scientific and technological developments in other countries is particularly important because it offers a wider range of solutions to technological problems. Building on their respective past technological strengths, different countries are specializing in different aspects or applications of biotechnology. Strategically tapping into the knowledge bases of other countries can help a nation develop expertise in areas in which the country is lacking, thus complementing its existing knowledge base. International technological cooperation (cross-border R&D collaboration) can provide local biotech firms access to the stocks of knowledge created by foreign systems of biotechnology innovation, enhancing their innovative capabilities (Bartholomew, 1997).

Developing countries, such as Taiwan, should support a more aggressive borrowing and adapting knowledge from more advanced countries as a means of accessing leading-edge scientific research. They should also encourage cross-border alliances with foreign institutions and companies for a wider range of potential

applications of biotechnology. The government, for example, could initiate international cooperative R&D programs, which aim to equip local firms with the capabilities for seeking and learning from the collaborative arrangements with foreign institutions and companies.

6.3. Conclusion

Taiwan government should carry out a more aggressively "diffusion-oriented" innovation policy. Programs, institutions and structural linkages should be established by the government for the purpose of facilitating industry's appropriation of new scientific developments, not just left market forces alone to direct the flow of knowledge between university and industry, which can not happen naturally under current institutional context in Taiwan. Besides, the practice of inter-firm collaboration should also be further reinforced by a stronger government role in coordinating pre-competitive cooperative R&D.

In short, the priorities for the development of Taiwan's biotechnology industry should be: higher levels of research funding; higher degrees of pluralism in funding sources; higher integration of research with teaching, clinical research and medical practice; higher reliance on interdisciplinary research teams; lower dependence on closed national systems; strengthening industry-university relations; creating "academic entrepreneurs".