A National Linkage Program for Technological Innovation[1]

KAVOOS MOHANNAK

ABSTRACT *A new perspective and conceptual framework of institutional linkages is explored and an institutional linkage model is developed. The model incorporates the linkage patterns and characterises major policy issues affecting technological innovation and technology transfer among the participating organisations. The development of the linkage model will draw on the insights provided by the literature on innovation. Particularly, it is argued that the nature and role of the linkage in technology development is a reflection of a generalised version of an interactive and systemic model of innovation which would suggest policy implications for promoting linkages and interactions within National Systems of Innovation.*

Keywords: technological innovation, institutional linkages, technology transfer, National System of Innovation (NSI), intermediaries.

Introduction

It was previously argued that the innovation process could be viewed as a linear flow of activities undertaken from the birth of a scientific idea to its evolution in the laboratory to its transformation as a technological tool and finally to the application of this technological solution to resolving an economic problem. However, recent models of innovation depict the process as being non-linear and characterised by multiple interactions, systems integration and complex networks. There are many individuals and institutions involved in this network such as scientists, technicians, government policy-makers, industrialists, financial institutions and, finally, the user of the technological application derived from the research. As a result, there is a need for the institutions involved in this process to adopt a unifying system framework that is individually and collectively part of one directed effort to bring a scientific solution to solve a productivity, and ultimately an economic, problem. It is within this underlying framework that policies should be defined, comprehended and acted upon.

In this regard, this paper proposes a conceptual framework and an interactive model of institutional linkages for promoting technological innovation and technology transfer. It is a general model to facilitate interaction and policy formulation to foster institutional linkages at the national level. The model is intended to show how different institutions can link and combine with other actors in terms of knowledge, equipment, personnel, and resources in order to produce effective interaction and technology transfer mechanisms. Furthermore, this approach looks at improving the effectiveness of the linkages within the broader framework of the National System of Innovation (NSI).

0810-9028/99/030323-14

From Linear Models to Interactive Models of Innovation

Innovation theories provide insights on how ideas are developed, diffused and commercialised, and therefore provide insights on how linkages can contribute to this process of innovation. However, analysis and theories of innovation describe it as a constantly evolving process. Until recently the older theories typically characterised innovation as a linear process; one in which an idea proceeds from a basic concept to development through research, and then to production. However, recent literature has shown that the linear model does not describe how the innovation process occurs.[2] Important themes that have arisen in the recent literature are continuous, iterative improvement, and more importantly the interaction nature of the process. There has also been more emphasis on the growing equipment and expertise requirements, fusion of the areas of science and technology, the difficulty of technology transfer and the importance of technology adoption.

As a result, the notion of a linear model has undergone significant revision. Key to the reconstruction is the notion of a continuous, iterative and interactive process of innovation. For example, Nelson and Winter have theorised that the process of innovation follows an evolutionary model, in which technologies continuously arise out of competition with each other.[3] Their model attempts to show dynamic characteristics of innovation versus the more static approach of orthodox economics. They point to the importance of organisational routines, search strategies and the technology selection environment that all serve to support continuous, iterative innovation. In this way, the process of continual improvement reflects a dynamic in which firms are constantly looking toward new ways of developing better products.[4]

Other models of innovation focus on intra-organisational dynamics, and illustrate a very interactive process of innovation featuring multiple sources of innovation. In the linear, functional form of organisation, the growth of an idea once generated is complicated by the levels of organisation that it must pass through. In this method of management, moving from conception to prototype, from prototype to production, and production to marketing, a technology must typically pass through several stages. Although there are efficiencies of management that derive from task partitioning, the partitions become barriers when the process requires interaction.[5]

These deficiencies have been addressed in Kline and Rosenberg's chain-link model and in Rothwell and Zegveld's non-linear model.[6] The Kline and Rosenberg model points to the importance of numerous feedbacks that link and co-ordinate R&D with production and marketing, the side-links to research along the central-chain-of-innovation, the role of long-range generic research for the back-up of innovation, and the essential support of science from the products of innovative activities. In Rothwell and Zegveld's model, the innovation process may be interactive, with re-design and re-development following testing and evaluation.

Therefore, in the linear view, R&D progress is a sequence of stages from basic science through to product and process innovation without any feedback. However, interactive view emphasises the feedback of information, especially from later stages of the process, and emphasises incremental and continuous aspects of the process. In fact, through linkages and interactions organisations are integrated and produce a dense network of information flows between them. Figure 1 shows schematically the close interaction and information flows in the various stages of the innovation process, from basic to technology development research, then to technology commercialisation, and finally to marketing. In this view various innovation stages are interacting in the entire coupling process.

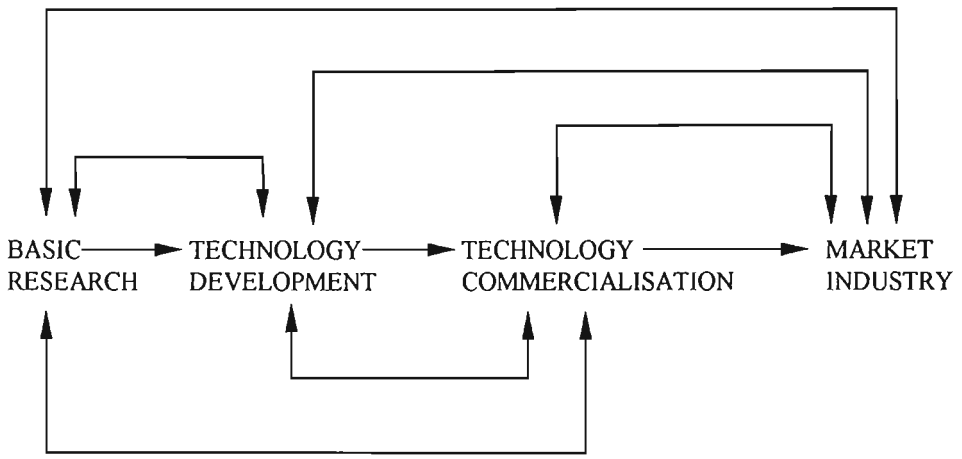

Figure 1. A simplified model of technological innovation involving feedbacks.

The interactive view also recognises the role of government policies in guiding and devising appropriate institutional linkages. The role of industry is emphasised in collaborating and receiving information from scientific and research organisations. Universities also play an important role in generating information and research results for industry and society as a whole. In general, the interactive view emphasises the importance of technical support in mediating the feedback of information flows operating from research to production. It also highlights the mediating role of capital necessary for commercialisation and development of new technologies. This system is, of course, placed within the context of broader surrounding systems–including the political and economic systems and the international and global environment.[7]

Therefore key themes that arise from discussion of innovation are the continuous, iterative and interacting features of innovation, and their matching to collective activity which might be enhanced through institutional linkages. More importantly, the interactive character of the innovation process calls for organisational structures and mechanisms to ensure the appropriate interactions and feedback inside corporations as well as among the various institutions that make up National Systems of Innovation.[8]

The Conceptual Framework

To develop the linkage model, three main considerations and assumptions based on interactive models of innovation are employed. The first and most important assumption is that, for technological relationships, the classical linear notions of demand-pull and supply-push are not enough to explain technological innovation. Rather an interactive view must be adopted which envisages a network of institutions.[9] These institutions include research and development and educational institutions, consulting engineering firms, private companies and public enterprises. Educational and other research and development institutions supply both capable human resources and technical know-how, while business enterprises supply the means and the opportunity to utilise the results of research and development for the production of socially desired products. Government often becomes involved as a stimulating guide for the efforts of others. Each element of the network will, in fact, engage in research and development activities in support of the others, and the network will be formed by effective linkages among them.[10]

A second assumption is that exchange relationships exist between government,

university and industry, and that these relationships create interdependencies and interactions between the organisations. The nature of the interactive process implies that there is a complex activity involving multiple actors and elements and a variety of different patterns of interrelationship and linkages. For example, linkages are not always on the basis of one-to-one relationships but may also be one-to-many or many-to-many. In addition, they may not proceed directly but may often operate through various forms of intermediaries.

A third assumption, therefore, considers that the intermediaries play increasingly important roles in the process of linkages and interactions between different members of the network. In many studies of institutional linkages, intermediaries are revealed as playing an important and evolving role in the linkage process.[11] As intermediate agents, they mediate relations and also provide liaison and bridging functions between public and private sectors. They are also able, in some cases, to provide complementary assets, through locating sources of technology or finance, for the development of technologies.

Based on these assumptions, a conceptual framework and a linkage model for the analysis of linkages will be developed that consists of three groups of variables: (1) the environment within which interaction takes place (macro-level factors within the NSI); (2) the participating organisations including intermediaries (micro-level factors); and (3) the interaction process. These sets of variables are further elaborated below.

The Macro-Environment (NSI)

This set of variables implies that the interaction is not taking place in a vacuum but must be seen as a part of a wider environment which can be described in terms of the structure and dynamism of the national economy, political and social systems. These environmental variables belong to macro-related factors.

Various case studies have shown that the path to create a successful industrial innovation can be seen as a series of macro- and micro-dependent exchanges. At the macro-level, these exchanges may include the national contextual factors that are comprised of combined economic, cultural, social and political factors. They may also include a wide range of institutional factors which impact on innovation: the institutional infrastructure (including education and training and incentive systems); the nature of co-operation and/or consensus in a country; the nature of government–industry relationships; demand-side factors; formal institutions concerned with searching and exploring, such as universities and R&D departments, and the nature of their relationships with government or industry.

It is the importance of these macro-level factors and the cumulative impact of their interaction that has led to the growing interest in the concept of a National System of Innovation. Thus, when this concept of a National System of Innovation was developed by a number of scholars and applied more widely on different situations of developed as well as developing countries, it was seen to encompass a range of institutions, including firms, higher education, publicly funded research institutes, the financial system and the procedures of training and apprenticeships.[12] Different case studies also reveal that systems of innovation can be stronger or weaker and certainly differ substantially from country to country.

A strong National System of Innovation is likely to be built around networks which Dahmen terms 'development blocks'.[13] Also the systemic concept implies that sets of interactive institutional actors play important roles in influencing innovative performance. Therefore, in the context of the National System of Innovation, it is very important for any country to develop a network of institutions that is termed here as the 'National

Linkage Program', which should aim to develop linkages between national institutions dealing with innovations. The rationale for the linkage model, therefore, includes the idea of creating organisational links and interactions between enterprises. Policies to achieve greater innovative activities will inevitably address this issue. Also, an efficient and viable policy must be put in place to encourage technology transfer among the linked institutions.

The Participating Organisations

At the micro-level, the participants are characterised by their expertise, organisational features and personnel. These factors can include communication and interaction within firms, interaction between firms (through forward, backward and horizontal linkages), and user–producer relations. The importance of these characteristics is demonstrated by the fact that the interaction can be seen as a means of linking different institutions to each other in an efficient way.

There are three main institutional groups in the linkage process. These comprise government policy-makers and other public or private research sponsors which provide fund and policy inputs. The second group is the public and private sector institutions such as universities and other public research organisations which provide an environment in which research is conducted. A third group is private industry which commercialises research and acquires technology for the purposes of developing commercial products. There is, however, another important group, termed intermediaries (both public and private) which play an important role as agents in building linkages among these institutions.

There are, of course, other types of entities that are directly or indirectly involved, most commonly by influencing the general environment in which interaction is attempted. Examples are financial institutions, professional societies, associations and conferences. Each organisation combines certain activities with matching resources in its interaction with other members, and the structure of the linkage can be constructed as this interaction takes place.

All institutions in fact interact and they are related to each other in a complex and multiple interactive systemic manner. The combination of all institutions creates a structure embodying a complicated set of roles. Some of the roles are complementary and are in this way able to be integrated with one another. However, technological innovation is the final goal of all the units involved in the network.

The Interaction Process

The interaction process is concerned with the relationships and links of individuals as well as organisations in terms of adaptations, contact pattern and linkage mechanisms. There is no single process which can encompass all instances of interaction and technology transfer. There are, for instance, many possible mechanisms: the use of facilities, co-operative agreements, consulting, third-party agents, joint research and staff secondments.

However, an important part of the collaboration and linkages takes place in the form of a technical exchange between different actors such as individuals or institutions. Accordingly, there should be a focus on interaction between different actors. In this view, innovation should not be seen as the product of only one actor but as the result of an interplay between two or more actors; in other words as a product of networked or linked actors.[14]

In this situation different kinds of institutions come together to create innovative situations. Thus, by combining experience and the contacts generated through linkages new ideas can emerge. A special case is when an exchange takes place between industry and a university. It means that the needs of the industry are confronted with the possible technical solutions known by the university. This provides an opportunity to revise and redefine both the needs and the available solutions and in this way find new possibilities. This is, in fact, an interactive effect and can be produced through different institutional linkages. In this way a linkage can help to create an interface between different specialists, thus producing a combination of several types of expertise.

Interaction processes therefore serve important functions in terms of efficiency and flexibility.[15] The most important implication of the existence of interactive relationships is that different organisations cannot be regarded as independent units but rather as units which interact with each other, constituting a network structure. In this structure units or organisations co-operate and link through a variety of mechanisms. Therefore this set of variables is mainly concerned with the various types of interactions between different organisations within an innovation-related network.

Model Development

To demonstrate the usefulness of the above conceptual framework, a linkage model is suggested that is structured to encompass the 'National Linkage Program'. To construct a model of the interactions between the participating institutions, it is better to begin by returning to the models of innovation.

However, the main difficulty with using these models is that their components are represented by the activity or stage in the innovation process, such as basic research, invention, design, development and commercialisation. The organisational or institutional interactions, in which this paper is interested, are not adequately represented. Thus, in the model that is formulated here the institutions are the components and the arrows represent linkages and interactions among them. It also recognises that technology transfer and diffusion between organisations are important functions of the linkage, and can accommodate these features.[16]

The objective is to show that the linkage model can be constructed from institutional or organisational components which are useful in identifying the nature and quality of linkages between main groups. In particular, the model highlights institutional interactions. These sorts of linkages are poorly specified in the traditional stage or activity models of innovation. In principle, this institutional approach can assist in the development of technology transfer strategies at a national level. In general, in order to be successful a high degree of co-ordination between the elements of a National System of Innovation in collaborative programs is required.

The linkage model that is proposed here considers implications of technology transfer and interactions within such models of innovation, identifying the components required to link the system together. Particular attention is paid to the intermediary roles which can be played by bringing about links within the system. Implications for government technology policy are discussed and examples of innovative government technology policies are also suggested.

Therefore, to emphasise the interactions, this section builds on the non-linear view of innovation outlined earlier, and is concerned with the development of relationships and linkages between different participating institutions in the process of technological innovation. These activities are linked by flows of information which are of crucial importance in a system involving R&D.[17]

National Linkage Program

As pointed out, the review of the models of innovation gives some insight into how linkages can help to facilitate innovation in a broader context. In general, linkages create an environment in which innovation through interaction can be generated. In fact, institutional links must develop the right organisational environment to help entrepreneurs gain the most from the resources of the other institutions, including business skills, education, access to equipment, staffing and ideas. On the whole, effective linkages help lead to innovation, which in turn facilitates economic development; itself relying on the growth of linkage activity by either existing or new scientific and technical research organisations.

An interaction model to facilitate the diffusion, transfer, acquisition and application of technologies can be conceptualised as the 'National Linkage Program'.[18] This linkage model may provide several services to its members and organisations, such as delivery of technological information, market & products information, and finance information. Through linkages it is also possible to encourage: strategic & operative consultancy and managerial education; applied scientific research; transformation of scientific results into useful technologies; creation and development of small enterprises; and transferring new technologies to applications.

The linkage model is a system which may be considered an important sub-system of the National System of Innovation, where the linkages help to create innovative projects between the organisations which offer technologies and the organisations which express innovation needs. On the whole, the collaborating projects bring together the achieving organisations and the financial sources, both public and private.

The 'National Linkage Program' has the following general objectives: (1) development of the economic process; (2) development of the competitive capacity of sets of companies; (3) generation of new technologies through interaction between knowledge producer and knowledge user; (4) commercialisation of research results; and (5) transfer of technology between the organisations. The role of the linkage model is especially emphasised with the technology transfer processes, generation of new technologies and services.

In particular, the linkage program will promote co-operation between universities and research centres with companies and organisations that would like to use the applicable technologies. The program will promote and develop the generation of new technologies while it organises and offers consulting services to companies through the role that intermediaries play. In performing all the above-mentioned activities the program will help to generate innovations.

The elements of the participating organisations of the linkage program consist of: publicly funded R&D institutions; government policy-makers; industry and entrepreneurs; financial institutions and development banks; and universities and higher technological institutions. Besides these institutions, other elements which play an important role in technology transfer are the intermediaries which would be able to link together all the institutions. Some of these intermediaries are in the public domain, such as different university liaison offices and Co-operative Research Centres. Other active intermediations are in the private sector. For example, consultancy and engineering firms, science and technology or economic foundations and engineering associations.[19]

Depending upon the perception of countries, their resources and availability of scientific and technological leadership, various countries have created different technology transfer modes and coupling mechanisms among their governmental, fiscal and technical institutions. Experience has, however, shown that even when the coupling

mechanisms were made, the communication gap between industry and universities was still very wide. Therefore, mechanisms had to be evolved for bridging these gaps and providing the various requirements which might help in building successful linkages.

However, a successful link and transfer of technology to one unit does not itself make an adequate impact at the national level. Through trial and error as well as by the deployment of scientific and engineering skills, an entrepreneur would have succeeded in receiving and adapting the technology for successful production.

The nature of the innovation process also dictates that different institutions which are involved in design and development of technology must develop backward linkages with each other, especially at the R&D stage. The backward route is based on the systemic view of innovation and also the concept of iteration and interaction, which are key features of the innovation progress discussed earlier.

Correspondingly R&D scientists in universities and R&D centres should also develop forward linkages with end-users and industry. This two-way interaction mechanism is essential for both designs as evolved in the laboratory and production and commercialisation of technology. If the R&D effort is market-oriented, the output of R&D effort is tailor-made and usually very close to appropriate technology.

Development of such backward and forward linkages can play a positive role in creating an effective interactive mechanism for the development of appropriate technology and innovation products and processes. However, an important aspect of these institutional linkages is that this type of coupling should not be limited only to laboratory personnel in university or research centres with industry. On the contrary, this type of linkage should include all the institutions involved in the development of technology, whether it be a government office or the financial institution, personnel should be prepared to work as a team towards the common objectives of successfully completing the project.

In this type of model, the intermediaries can act as the agents of technology transfer and develop expertise in the methods of technology transfer. These intermediaries are able to devise mechanisms for utilising different institutions required in the collaboration process and have given themselves the prime role of facilitating technology transfer and interaction between different actors involved in the project. Their strategy could involve strong institutional linkages with R&D centres on the one hand and industry or financial institutions on the other. In acting as leaders, these intermediaries can provide a complete technology package with performance guarantees and act as a single focal point for an entrepreneur in negotiations.

By considering the model as a communicative and interactive process with multiple feedback loops, it is possible to make the role of the intermediary in this process more evident. According to Anderson, in a simplistic sense, one can distinguish two general ways in which interaction and linkages through intermediaries work. These are the 'direct' mode and the 'systemic' mode, as shown in Figure 2.[20]

In the direct mode, as the name implies, the intermediary is directly in the path of communication and interaction flow. All the information passes through the intermediary from one institution to other, as does all the feedback from the institutions. The systemic mode is the opposite case. In this mode, all the interaction occurs directly between the institutions and the role of the intermediary is to set up the two-way communication channels and then monitor them to be sure that all goes well. In other words, intermediaries in this case act as a control node, connecting the two parties involved.[21] These simple roles of intermediaries will help to construct more complex and hybrid models of interaction, which include additional institutions, and require greater networking activity.

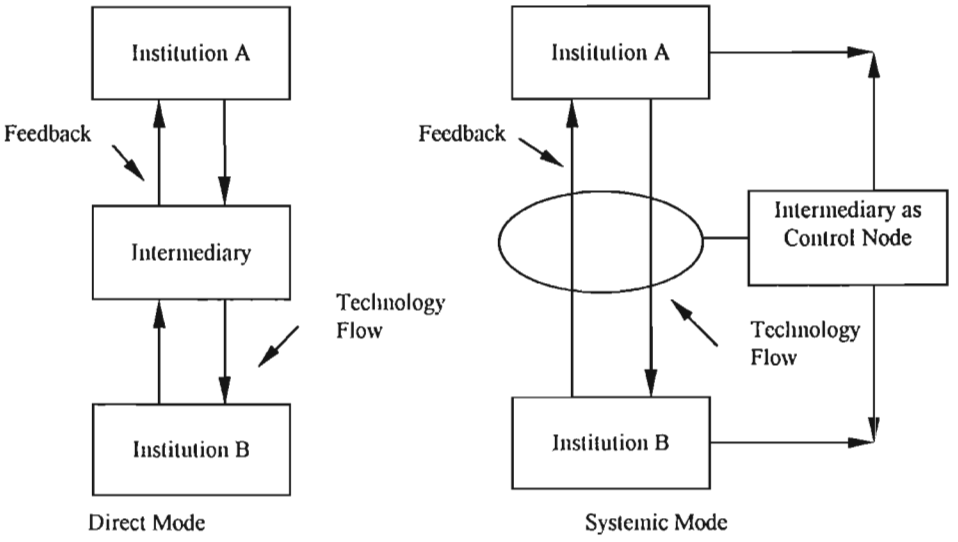

Figure 2. Two-models of technology transfer through intermediaries.
Source: Adapted and modified from Ref. 19.

In general, the intermediaries can play various roles in the process of interaction and institutional linkage, depending on the type of intermediary. These roles can include: marketing/business consulting; brokering companies strategic alliances for technology transfer; networking facilitator; translation between cultures; special project management; education and training; and technology distribution channel.[22] There is also a variety of intermediaries, both in the public and private sectors. For present purposes, it may be better to group them into two broad public and private sector intermediaries. By taking advantage of the many services available from both these sector intermediaries and incorporating them into their activities, research institutions can effectively leverage their own limited resources.

On the whole, the interactive mechanism among institutions ensures that R&D work develops smoothly and determines whether additional inputs are essential or not. Furthermore, at each stage of development of the process, working expertise and the experiences of the different agencies involved go into the project and should make the process workable. The role of the intermediary for each stage would be very important and will determine the success or failure of a project. Therefore, the main feature of this model is that there would have to be a tremendous amount of back-and-forth communication and interaction between different agencies and groups. However, for co-ordination and leadership, some main agencies such as the intermediaries must emerge.

In this model, the success of transfer and linkage depends on the transmitter, the receiver, the technique, the channel of transfer, and the climate. In each of these areas, gaps, if any, should be identified and bridged to ensure successful transfer. The success of the transfer and linkage operation also depends on proper evaluation of the process. Therefore, a two-way evaluation mechanism should operate and determine the progress of the project. Ultimately, the success of technology transfer depends to a large extent on the resourcefulness of the entrepreneur, who must have the necessary background to understand, assimilate and commercialise the technology.

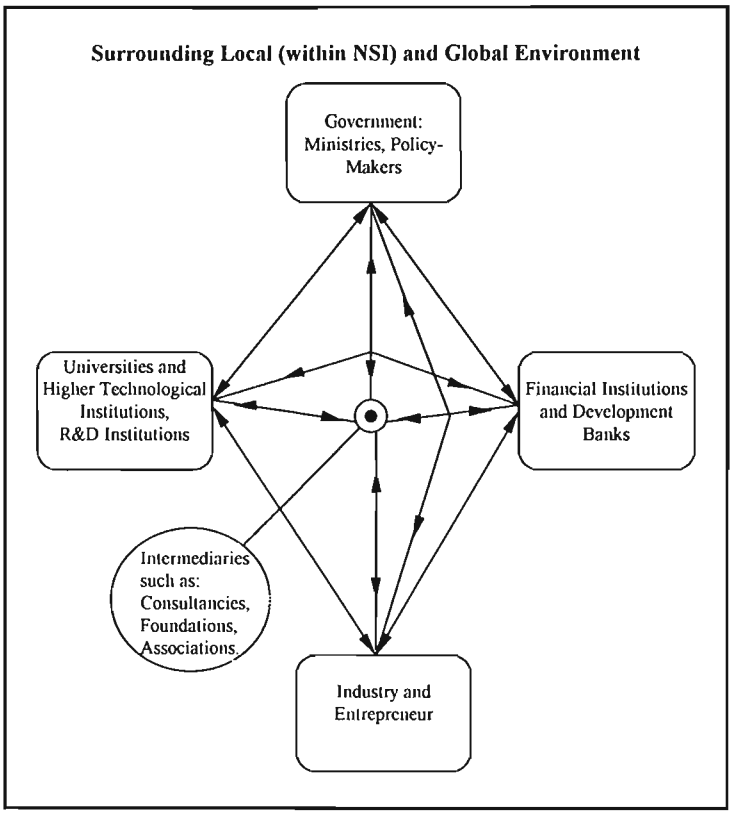

Figure 3. A model of multiple interactive systems and coupling mechanisms of institutional linkages.

In general, this model represents a multiple interactive system with coupling mechanisms and has a trigonal bipyramid structure. The main elements of this model, which have to work together for technological innovation in general and transfer in particular, are graphically illustrated in Figure 3. Effective interfacing and dynamic interaction as illustrated can bring about the much needed technological transformation through indigenous R&D.

Policy Implications

As discussed, technological innovation and linkages between R&D institutions and industry involve a highly complicated operation. There are many factors–such as the status of the technology, capability of the entrepreneur, markets, government regulations, macro-economic policies and availability of raw materials–which influence the successful establishment of commercial production.[23] However, by studying cases of technological innovation, some broad features can be identified as to the factors that go into making a linkage program operation a success or failure.

Broadly speaking, while it is not possible to suggest a definitive set of policies and tools appropriate for the success of a national linkage program, it can be said that whatever policies are adopted should contain at least some important features. For example, the actions of the various institutions that participate and implement policy and

programs should be co-ordinated in order to avoid contradictory measures, especially those pursued by the different parties involved. This is also the case at the macro-level, where the linkage program, innovation policies and general macro-economic policies must cohere. In other words, effective and successful linkage can occur only when government achieves overall policy coherence.

Another feature is that linkage policy should be consistent with innovation and industry policies and be flexible. Policies must be capable of responding to changing industrial needs and opportunities. Also, through learning-by-doing, greater inherent flexibility might be achieved. In other words, linkage policy measures should incorporate continuous evaluation, with positive feedback to the policy system in order to improve policy effectiveness.

Furthermore, a national linkage program should not only complement each participant, but also the strategic interests of other domestic companies. This means that policy-makers should be aware of the long-term strategic thinking within major national companies.

Policy-makers must also recognise the inherent limitations of a national program and accept them. Policies should thus be based on a realistic assessment of industrial potential. In other words, public policy-makers should recognise their own limitations, because over optimistic expectations might result in termination of promising initiatives. While, in consultation with industry and universities, public bodies might be involved in the selection of rather broad areas of innovation activity, the choice of individual projects is probably best left to consultation with industrial and academic experts in the field.

However, government can help identify relevant linkages between institutions. In many situations the grouping of units into a single network is not applicable as important relationships often cross industrial boundaries. For example, governments could help to bring together different industrial companies belonging to the different sectors and harmonise their relationships for the purpose of technological innovations. The success, for example, of the Japanese government policies in bringing together different companies has increased interest in these types of policies.

In addition, a government can act to balance and handle the power structure within the network. If the power structure within the network is not understood and handled in the right way, a good idea or product can be ignored or can be easily blocked if strong interests are mobilised against the development of the product or idea.

Government may also create and encourage exchange between different technical areas. This can be in the form of technical meetings, occasionally through conferences, more permanently as science and technology parks, or through joint projects between companies from different industries. The aim is to enrich and fertilise the linkage structure, to include new companies, and to develop relationships.

Therefore, a government can help to encourage and strengthen the network structure and to bring within the innovation system strong support with the view that it is the overall system and the quality of interconnections within it which affects successful technological innovation.

Concluding Remarks

The commercial success of technological innovation almost invariably depends on the collaboration of complementary resources and skills. Innovators and entrepreneurs need to accept the need to come together with a financier, manufacturer or marketeer, and to accept that a product or process can only be successfully developed when people combine their resources, experiences and expertise.

A mechanism, like the proposed 'National Linkage Program', would be able to link and co-ordinate R&D centres, entrepreneurs and financial bodies in order to foster institutional linkages and technology transfer. This proposal in policy-making attempts to enhance the effectiveness of government interventions to promote technological innovation, especially a government's intention to encourage R&D linkages. It is suggested here that by encouraging such an attempt, the participating organisations begin to pay attention in increasing efforts to improve products and processes through the improvement of knowledge in science and technology, research collaboration, research and development, and innovation.

Regarding the innovation process, this paper has argued that linear models of innovation cannot describe fully the process of innovation. Therefore, the paper has attempted to demonstrate the need to see innovation and technology transfer as an interactive process and has presented a conceptual framework comprised of: macro-environment factors; participating organisations; and the interaction process, for the clarification and analysis of that interactive process. It has also outlined the need to view that process from multiple interactive perspectives, with an important role for intermediaries, rather than from a single linear form of relations.

Notes and References

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7. Freeman, based on the Maastricht Memorandum, also summarises the main characteristics of a systemic model of innovation as: '1. Multidirectional links at the same point in time between the stages of technical change. 2. Cumulative processes over time can lead to feedbacks and lock-in effects. 3. Technical change is dependent on knowledge and the assimilation of information through learning. 4. The details of the development path and diffusion process for each innovation are unique. 5. Technical change is an independent and systemic process'. See C. Freeman, 'The greening of technology and models of innovation', *Technological Forecasting and Social Change*, 53, 1996, p. 31.
8. A recent study by Etzkowitz and Leydesdorff suggests another non-linear model of the innovation process. According to them: 'a spiral model of innovation is required to capture multiple reciprocal linkages at different stages of the capitalisation of knowledge'. The involvement of universities, industry and governments in the process therefore results in a 'triple helix' model of innovation. As the biological metaphor indicates, this is an evolutionary model. Etzkowitz and Leydesdorff assert that this triple helix of university–industry–government relations is likely to be a key component of national and multinational innovation strategies. See H. Etzkowitz and L. Leydesdorff, 'The triple

helix of university–industry–government relations: a laboratory for knowledge based economic development', *EASST Review*, 14, 1, 1995, pp. 11–19.

9. Freeman, however, in a recent paper argues that: 'To realise large technoeconomic system transitions, society needs to develop a new model of innovation, combining some features of the much criticised linear model with features of the systemic innovation model'. For more elaboration of this argument, see C. Freeman, *op. cit.*, p. 27.
10. This assumption is based on the fact that numerous case studies of innovation point to the importance of flows of information and knowledge between firms as well as within firms. Moreover, the results of empirical research point to the importance both of flows to and from sources of scientific and technical knowledge and of flows to and from users of products and processes. See B. A. Lundvall, 'Innovation as an interactive process: from user–producer interaction to the national system of innovation', in G. Dosi *et al.* (eds), *Technical Change and Economic Theory*, Pinter Publishers, London, 1988, pp. 349–69.
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13. E. Dahmen, 'Development blocks in industrial economics', *Scandinavian Economic History Review and Economic and History*, xxxvi, 1, 1988, pp. 3–14.
14. In fact, technical exchange is an interactive process, and what is transferred takes many forms–knowledge embodied in people, and in codified form in publications and patents. It is the process of movement between actors (whether individuals or organisations) of these forms of knowledge and information, and the accompanying contractual, financial and economic relations that is also referred to as technology transfer. For a model of knowledge transfer, see M. Gilbert and M. Cordey-Hayes, 'Understanding the process of knowledge transfer to achieve successful technological innovation', *Technovation*, 16, 6, 1996, pp. 301–12.
15. This is because it is through interaction that information is transferred and thus the interaction process can stimulate or inhibit the efficient technical exchange between the actors.
16. Gibbons *et al.*, while discussing the Mode 2 knowledge production, suggest that 'the notion of technology transfer has to be reconsidered'. They maintain that 'technology interchange is a more appropriate phrase than technology transfer'. This is because Mode 2 knowledge production involves the close interaction of many actors. For more information, see M. Gibbons *et al.*, *The New Production of Knowledge*, Sage Publications, London, 1994.
17. Brown and Karagozoglu also provide a systems model of technological innovation based on two specific types of inputs to the innovation systems: (1) decision inputs; and (2) implementation inputs. For more discussion about their model, see W. B. Brown and N. Karagozoglu, 'A systems model of technological innovation', *IEEE Transactions on Engineering Management*, 36, 1, 1989, pp. 11–16.
18. For other models of technology transfer, see, for instance, R. A. F. Seaton and M. Cordey-Hayes, 'The development and application of interactive models of industrial technology transfer', *Technovation*, 13, 1, 1993, pp. 45–53; P. Trott *et al.*, 'Inward technology transfer as an interactive process', *Technovation*, 15, 1, 1995, pp. 25–43; and C. Chiarella *et al.*, 'Innovation and the transfer of technology: a leader–follower model', *Economic Modelling*, October, 1989, pp. 452–6. Among these writers, Seaton and Cordey-Hayes have drawn attention to many of the limitations and deficiencies in traditional technology transfer mechanisms and presented a model of technology transfer (accessibility–mobility–receptivity) which emphasised the interactive nature of the process. Their study was followed by a subsequent paper by Trott *et al.* which focused on the concept of 'receptivity' and developed a conceptual framework which identified four major components for the inward technology transfer process in firms. These are: awareness, association, assimilation and application.
19. L. K. Anderson, 'Technology transfer from federal labs: the role of intermediaries', in S. K. Kassicieh and H. R. Radosevich (eds), *From Lab to Market: Commercialization of Public Sector Technology*, Plenum Press, New York, 1994, pp. 183–94.

20. Anderson names these two models as 'conduit' and 'control system' models. See Anderson, *Ibid.*
21. *Ibid.*
22. *Ibid.*
23. For example, in order to show that many factors are involved for a successful innovation, Dunphy *et al.* studied the influence of global, national and micro level factors on innovation. They argue that these factors provide the critical path through the innovation funnel. See S. M. Dunphy *et al.*, 'The innovation funnel', *Technological Forecasting and Social Change*, 53, 1996, pp. 279–92.