Paradigmatic Shifts in National Innovation Systems [1]

Riccardo Galli and Morris Teubal

PART 1

1. Introduction and objectives

1.1. Introductory remarks

Profound changes are taking place in the world economy and in the innovation systems of countries. The main influencing trends could be summarized by the terms globalization, liberalization, dematerialization, and technological revolution. Their joint effects have been the enhanced uncertainty and turbulence felt in the world economic system since the 1973 crisis and the gradual emergence of a different rationale for production and innovation. The techno-economic mass production paradigm of the past is gradually giving way in an increasing number of sectors to a new paradigm characterized by flexible manufacturing and the pervasive effects of the cluster of the so-called information technologies (IT) (Freeman and Perez, 1988; Piore and Sabel, 1984; Womak *et al.,* 1990), based on the convergence of microelectronics, computers and telecommunications.
This chapter deals with paradigmatic changes and structural adjustments of national systems of innovation (NSI) and related economic policies. In the past, structural changes in the organization of science and technology (S&T) have been associated with paradigmatic transitions in order to best fit the features of new emerging and dominating technologies. Freeman (1987) describes the evolution and progressive appearance of new kinds of institutions and mechanisms for technological development and professional education within NSIs *pari passau* with successive technological revolutions and associated techno-economic paradigms. Early institutions such as universities, scientific academics, and professional associations were followed by industrial R&D centers and eventually mission-oriented public research centers. Important [2]mechanisms developed gradually: in the second half of the nineteenth century we observe the emergence of national and international patent protection systems, and later on, interfirm technology transfer mechanisms, interfirm technical cooperation, and industry-university relations. Current NSI structures are, therefore, the result of a historical evolution induced by a succession of techno-economic paradigms. The transition we are currently experiencing has brought about further structural adjustments of NSIs, which are already detectable. The goals of this chapter are to provide:

- a schematic description of paradigmatic and structural changes occurring in NSIs;
- a presentation and analysis of the central elements of a possible model of NSI and NSI transition;
- a contribution to generating an evolutionary policy framework for system evolution and transition;
- a basis for an institutional approach to NSI data collection.

Our analysis is based on critical observations of the behavior of the innovation systems in a number of industrialized countries. Despite obvious differences in the characteristics of NSIs, general trends in the direction of change appear to be relatively homogeneous, at least at our level of analysis, although the stage of the transition could differ significantly across countries. While falling short of presenting a full-blown analytical model of system transition, our 'appreciative' theorizing hopefully provides some structure to the discussion of system transition including some aspects pertaining to policy.

[1] We owe special thanks to E. Andersen, S. Jacobsson, F. Malerba, and P. Saviotti for detailed and insightful comments on a previous draft, and to D. Foray and L. Soete for specific comments. Due to space constraints we have been extremely limited in our capacity to integrate them fully into the text.

1.2. Market and non-market coordination

Systematic evolution has had profound influence on industrial, technological, and economic policies in the past, and will have even more so in the future. One reason for its rising influence is the growing importance of non-market coordination resulting from the increasingly systemic nature of innovation (Teece, 1992) and, more generally, from the fact that national economies and the world economy are increasingly becoming integrated into (more complex) systems with markets only gradually, and to a limited extent, taking on coordination functions. Once an economy becomes a system, rather than a simple array of sectors, it is necessary to find mechanisms for coordination its various interacting and interconnecting components. Market coordination is one possibility but its materialization will take time (see market building below). It is likely that other types of coordination will be found with competitive advantages over the market mechanism. These might include: institutional mechanism, networks, bureaucratic (policy) mechanisms, and even political coordination.[2] Thus the increased systematic nature of the economic, by virtue of enhancing overall coordination needs will potentially increase the scope of both market and non-market coordination mechanism. One of the objectives of policy will be to pave the way for the establishment of a pattern of systems of governance in the economy which may address such coordination needs.

The discussion above naturally implies an increased focus on changing and adapting institutions, both as a framework for (an enabling factor in) market coordination (market building) and to assure effectiveness in non-market coordination. Over and beyond their role in markets, institutions provide a legal framework for enabling transactions to take place directly among independent market agents without the intermediation of an organized market, and they set appropriate rules within non-market organizations, such as universities (which, e.g., enable effective coordination with both government and business sectors). Thus, they underpin both (actual and potential) market-based and non-market systems of governance. Frequently they also are the non-market coordinating mechanisms themselves.[3]

This chapter has two main parts. In Part 1 we discuss some general trends characterizing (or emerging from) the new techno-economic paradigm together with implications for NSIs (including differences with the established NSI configuration). Beyond being more complex and more open, the new system calls for a profound restructuring of existing sectors. It will include an explicit infrastructural sector involving both new infrastructural components and a policy development block or policy subsystem. In Part II we present a simple, bare bones, conceptual model for analyzing what we have termed system transition. One objective is to develop a system view of industrial and technological policy, based on the evolutionary approach to economic change, which has as its principal purpose the support of desirable system transition trajectories. A main conclusion is that institutional change is critical for NSI transition to complement the actions of atomistic market forces involved in the restructuring of the industrial sector. Moreover, frequently an important component of such change must be anticipatory rather than market led and endogenous (or demand pulled). This, very likely, will have to involve bureaucratic, institutional, or political processes. We surmise that while the market mechanism and its enhancement are critical, exclusive reliance on them may frequently lead to truncated or imperfect NSI transition trajectories.

This chapter assumes that the kind of modeling prevalent in economic theory, and represented today by the new growth theory, is incapable of describing either current economic changes or the emerging new system configuration. We emphasize instead that an explicitly systemic conceptual framework and approach must be adopted both for analyzing the real world and for policy, which at this juncture can only be based on a renewed understanding of reality.

---

[2] When discussing the limitations of the market failure approach to justifying government intervention in the economy, Nelson (1987) states that there might be certain kinds of public goods (e.g., infrastructures) that governments rather than market forces may have a relative advantage in supplying. Similarly, the efficient execution of certain types of coordination functions may have to involve governments directly rather than the market or other mechanisms. More generally, government policy will influence all systems of governance, whether market, bureaucratic, political, or other.

[3] These issues are rarely discussed in either policy-related work or, more generally, within the neoclassical economics tradition, although lately some concessions have been made by discussing general infrastructures such as education, as critical factors in successful economic growth (see World Bank, 1992). Traditional productivity analysis can only tell us something about the average rate of return to R&D in the economy, but cannot, even remotely, address the issue of restructuring innovation and technological policy, the central policy issue in this age of turbulence and fundamental uncertainty. The reason, again, is the lack of a conceptual and systemic framework of the R&D/innovation process from which the institutional underpinnings of policy could be delivered.

2. National innovation systems: main components and salient features of their evolution

2.1. Background

The technological revolution has, since the late 1970s, induced numerous changes in the conditions and behavioral patterns that characterized post-war economies. For our purposes some of the salient changes are or pertain to:

- a widening of technological options (and the enhanced importance of the “search” function in firms);
- enterprise restructuring (e.g., decentralization);
- enhanced scope and variety of technological cooperation (e.g., precompetitive R&D consortia; and university-industry cooperation);
- a trend towards the internationalization of R&D.

These changes are linked with recent trends in NSI such as:

1. the critical role of linking organizations of all kinds performing technology needs coupling or intersectoral coordination functions in situations where markets do not yet exist;
2. basic market-oriented technological infrastructures (see Justman and Teubal, 1995) set-up in part to help individual firms (particularly SMEs) to face the managerial challenges opened up by the widening of technological options;
3. the importance of soft infrastructures, both information and advice concerning innovation in connection with health, education, culture, leisure, etc.;
4. increased complexity (e.g., the number and types of links among NSI players).

2.2. The notion and evolution of the NSI concept

The above-mentioned trends toward increased system complexity are also affecting S&T: the traditional concept of R&D system has been widened to that of innovation system, reflecting the need to link the generation of scientific and technological knowledge with the diffusion, transfer, and application of R&D results. This is the basis for the case studies and comparative analyses of national innovation systems in Nelson (1993) and Lundvall (1992). In this chapter we emphasize the role of an infrastructural subsystem involving technical and soft supporting functions as well as policy development mechanism.
We follow the usual definition of NSI as the set of organizations, institutions, and linkages for the generation, diffusion, and application of scientific and technological knowledge operating in a specific country. The concept of national system had a well-defined meaning in the past when basic decisions concerning the science, technology, and innovation policies of a given country were taken essentially at a national level. Nevertheless, increasingly, international linkages are dominant in science as well as in innovation and diffusion processes, leading NSIs to become ever more open systems. Thus the term may appear a mismatch to the current real geographic size and space of technical systems supporting innovation in any specific sect or, which might be mostly international. Moreover, the national borderline is now less meaningful because national power is flowing partly upwards towards supranational institutions and partly downwards towards regional and local institutions. (These apparently conflicting trends are themselves largely due to inherent characteristics of the new paradigm; see Galli, 1992.)
Nevertheless, the concept of national system maintains its significance not only because it is shaped by national characteristics - size, social and economic development, sectoral specialization, endowment of resources, cultural traditions - but also since the required adaptation to the new paradigm is still largely done at the national level. Thus the speed, coherence, and completeness of the required changes vary, often significantly, from country to country.

Following North (1994: 360) NSI organizations would include: political bodies, such as ministries or national councils for S&T; bureaucratic bodies, e.g., public agencies and offices implementing innovation policy; regulatory bodies, e.g., for standards, norms, and certification; social bodies, like academies and professional associations; educational bodies, like universities and schools; knowledge-oriented bodies without economic goals, e.g., government laboratories in the area of defense or health, or non-profit organizations with economic goals, e.g., a technical center or experimental stations of an industrial association; profit-oriented firms, including R&D companies, joint ventures, consortia; and bridging bodies connecting the S&T realm with the needs of business firms, such as innovation centers, associated with chambers of commerce or industrial associations, or the industrial liaison units of universities.
Institutions, in contrast, are made up of: fermal constraints, such as patent laws, formal criteria for allocating resources to science, peer review procedures, technical standards and norms, etc.; informal constraints, such as norms of behavior, conventions, codes of conduct, etc.; and their enforcement characteristics (North, 1994; Edquist and Johnson, this volume). Together they define the incentive structure of S&T and innovation/diffusion activities operating in a specific country.

2.3. NSI functions and linkages

Functions

The components or building blocks of an NSI comprise groups of organizations sharing some common characteristics and institutions governing tile relations within the group. After World War 11, NSIs developed within a relatively well-defined sectoral or subsystem configuration schematically based on three R&D performing sectors (business sector, public sector, and universities), with relatively weak linkages among them, and a fourth basic infrastructural subsystem (bureau of standard, patent office, etc.). Every organization within a building block predominantly performed a specific role or function. For universities, it was higher education and basic research; for government labs, mission-oriented research; for business firms, applied research and technological development.
Nowadays it is necessary to distinguish between function and organization, ,as the latter tend to play increasingly multiple roles. A useful distinction is between hard functions, requiring hard organizations (i.e., equipped with laboratories and performing R&D), and soft functions, which may be operated within soft organizations (i.e., without laboratories and not performing R&D) and involve catalytic and interface roles only. A major distinctive trait of the new NSI configuration is related to the emerging and crucial role of soft functions, and hence related organizations, because of the increased intensity of links among building blocks.

Hard functions and related organizations include:

- R&D, involving universities and public (governmental, local, mixed) and non profit organizations;
- supply of scientific and technical services to third parties (business sector and public administration) by industrial firms, technological centers, technical service companies, universities, governmental laboratories, and ad hoc organizations.

Soft functions and related organizations include the following:

- diffusion of information, knowledge, and technology towards economic and public operators acting at the interface between knowledge suppliers and users; such bridging organizations include various forms of innovation centers and liaison units universities and public labs, etc.;
- policy-making by government offices, technology assessment offices, academies, universities, ad hoc fora, national committees and councils, etc.;
- design and implementation of institutions concerning patents, laws, standards, certifications, regulations, etc.; these functions are usually performed by public or intermediate organizations;
- diffusion/divulgation of scientific culture through science museums, science centers, etc.;
- professional coordination through academies, professional associations, etc.

Linkages

It is important to present and characterize the linkages connecting the various players or components. Three types of linkages may be identifies:

1. Market transactions, such as Hirschmann's backward and forward linkages (Hirschmann, 1956).
2. Unilateral flows of funds, skills, and knowledge (embodied and disembodied) within an NSI as well as externally, between organizations and others located in other, countries or NSIs.
3. Interactions, such as user-supplier networks.

Unilateral flows and interactions take place when markets do not exist or are underdeveloped (or when the market mechanism is not the appropriate one for mediating between supply and demand): e.g., the flows of skills from universities to the business sector could involve an externality. In some cases institutional linkages may evolve and eventually give way to market mechanisms or to a larger dose of market mechanisms (see below).[4]
We now move to consider the various NSI blocks, one at a time. Due to space constraints the presentation is only schematic.

2.4. Universities

Universities represent in some sense the cornerstone of innovation systems, with a responsibility for providing higher education and performing basic research. However, growing links with application, an increasingly blurred borderline between science and technology in frontier areas of research, the need for interdisciplinary approaches in complex problem-solving, and the huge size of required resources in many scientific projects represent new challenges for university management and have led to the establishment of new institutional approaches within the subsystem (see Meyer-Krahmer, this volume).
Emerging major trends concern:

- the growth of multidisciplinary research;
- the diffusion of generic or mission-oriented research programs;
- stronger interaction with the business sector as a means to monitor and assess the achievements of basic research as well as to direct the performance of scientific activities;
- the establishment of interface units, offering the business sector new organizational mechanisms to access the internal capacity, skills, and know-how of university laboratories, thus reducing the business sector-'s transaction costs (a paradigmatic example is the Industrial Liaison Program of the Massachusetts Institute of Technology);
- the establishment of joint research/technology, development organizations: examples are the university-industry research centers established by the National Science Foundation in the USA and involving both public and private sector-financing.

2.5. The public sector

There are three major kinds of public R&D organizations:

- mission-oriented bodies and agencies supplying the required scientific and technical support to ministries and other national or regional authorities. Typical examples in most countries are the national health institutes, the space agencies, the military laboratories, the extension service agencies, environmental institutes, etc.;
- basic or general bodies, often articulated in several centers (e.g., CNRS Institutes in France, Max Planck Institutes in Germany, CNR in Italy, etc.);
- public owned companies (which generally operate in such sectors as oil and gas, minerals, utilities, railways, telecommunications, etc.) often play critical roles in NSIs, because of the relatively high share of

[4] Linkages can be facilitated, enabled, or embedded in a wide variety of institutional arrangements, e.g., laws, norms, and traditions; regulations; policy-induced incentives and disincentives; specific allocation and decision-making mechanisms within formal institutions; agreements; alliances; cooperation agreements; exchanges; etc. Interaction among S&T operators may take place in a variety of spaces and dimensions. Their context can be related to geography, technology, or industry. Government policy is a major enabling factor in the generation of linkage mechanisms and incentives.

country R&D performed in the laboratories of these companies as well as their role in defining technical standards to a vast number of supplying firms.

The public sector of NSIs is undergoing strong restructuring in most countries and is adopting a new role in supplying scientific and instrumental capabilities to the business sector and a much stronger market orientedness. This is a result of budget cuts and the ensuing crises of many R&D agencies and organizations, which forced the laboratories to look for new roles while keeping highly sophisticated skills and knowledge. The result of all this has been attempts at marketing research services to ensure the survival of the organizations. In support of this trend, government laboratories often organize ad hoc structures dedicated to the promotion, commercialization, and diffusion of their know-how (Tassey, 1991).
Deep restructuring is also taking place in the scientific and technological activities of public owned companies, largely because of privatization or budget constraints, with a concomitant reduction of their public role in keeping some fundamental research activities and in supplying standards and technical services. The prospects of these laboratories may evolve, depending on the case, either in the direction of reductions in size and associated elimination of non-strategic activities (and in some cases, maintaining minimum trouble-shooting capabilities exclusively) or towards a clear market orientation profile based on the restructuring of existing activities with scientific services now becoming a new business line.

2.6. The business sector

The private business sector is based on enterprises and their R&D laboratories, which play a fundamental role in performing research and technological development.
Major changes are taking place in the innovation process within firms: the shift of emphasis from an R&D based linear process to a model emphasizing the full integration of roles among technical and market functions and the external provisions of information, technology (embodied as well as disembodied), and advisory service. All this leads to changes in the current configuration of this building block, which is more articulated than in the past. These changes include:

1. An increase in the scope, frequency, and variety of interfirm links not mediated by the market.
2. An intensification of linkages between customers and suppliers, typically at the extremes of the production chain. Commodity manufacturers (steel, metals, plastics, fiber, paper, functional chemicals, cement, etc.) are in general large companies equipped with application laboratories supplying their customers with know-how on the best utilization of their products. These services are instrumental to the strong ties connecting these firms with their customers. On the other end, we observe system companies (automobiles, appliances, consumer electronics, aerospace, defense, etc.) with strong R&D facilities which assemble subsystems and components. These system companies play a critical role in updating and maintaining the technological level and production quality of their suppliers. A third critical category of mutual interaction concerns links between plant and equipment suppliers and their customers.
3. The spread of R&D contractors, i.e., independent companies generating technical knowledge to third parties. Specialized technology supply organizations may have either a general scope (i.e., operate on a wide spectrum of S&T areas) or a specific scope, such as a single technology (e.g., soldering, chemical analysis, machine tools, automation and robotics); they may also specialize in a single material (plastics, rubber, steel, non-ferrous metals, etc.) or problem area (e.g. environmental protection, quality and certification).
4. The spread of engineeriiig, consulting, and information service companies: this follows from the enormous increase in technological options available and the associated need to access an increasingly varied external technological base; globalization, in our opinion complements this trend in further stimulating the emergence of markets for consultancy services and even for technology.

2.7. The new infrastructural components

In the transition to a new NSI the establishment of different elements of infrastructure may play important and active roles both in business sector restructuring and in promoting greater interconnectedness among the various NSI components. The infrastructure supporting technology and innovation in any NSI may be divided into three main subcomponents.

- a traditional basic infrastructure, which includes organizations engaged in soft functions (such as patent offices) and hard functions (such as infratechnology, i.e. novel measurement technologies upon which new product standards will be based; see Tassey, 1991). This subcomponent would also include the bureau of standards, geological surveys, extension services, statistical offices, science museums, science centers, etc.;

- the innovation or technological infrastructure (TI), including both basic and advanced components (Justman and Teubal, 1995), whose more novel elements - both soft (e.g., interface units) and hard - could play the active role in system transition;
- a policy development block.

Our presumption is that the transition from the old to the new NSI requires strengthening the roles of the basic infrastructure, significantly expanding the TI block, and radically restructuring and increasing the scope of the policy development (PD) block. Since an ideal transition requires an unusual level of overall policy coordination and novel innovation infrastructures, it is justified to separate significant portions of the PD and TI blocks from the non-infrastructural components of the system which they serve (at least during the transition period up to the point where likely they again become well reintegrated with the other sectors).[5]

2.7.1. The innovation infrastructure

Probably the most significant change in the infrastructure supporting S&T relates to the innovation infrastructure in the form of both hard organizations, such as technology centers and institutes (either sectoral or functional), and of soft organizations, such as innovation centers and similar bridging organizations. The latter involve new mechanisms, initiatives, and organizations with a catalytic interface role among NSI sectors or subsystems.
Concerning the hard components - which are frequently embedded in organizations involving important soft elements as well - it is important to emphasize their rapid absolute and (apparently) relative growth in recent years. For example, RTOs (research and technology organizations) in Europe grew significantly since the mid1980s till the early 1990s (SPRINT, 1994); and so did the NSF-sponsored University-Industry Research Centers (Cohen *et al.,* 1994). In microelectronics, a wave of technology centers was created in the 1980s in the wake of significant advances in the application possibilities of this technology family (e.g., IMEC in Flandes, SIM in Stuttgart, CESM in Neuchatel, etc.). Similar centers were created for other generic technologies (optronics, biotechnology, factory automation, etc.).
Parallel to the creation of new technology centers, a process of restructuring existing centers is also taking place. Trends seem to be similar to those mentioned above in connection with government laboratories: enhanced demand orientation; changes in the structure of ownership (enhanced private participation); greater involvement of industry including manufacturers associations, chambers of commerce, and networks of firms; greater international links; establishment of mechanisms for setting priorities in new capability development; reformulation of links with academic institutes; and greater emphasis on diffusion of technologies and provision of technological services. Finally, it should be noted that an important segment of the collaborative R&D programs within the European Union involves pre-competitive generic research, leading to the development of generic technologies or capabilities serving a number of users and uses (Justman and Teubal, 1995).
Coordination needs and decentralization policy are two major determinants of the most peculiar phenomenon taking place in the infrastructural subsystem, that is, the establishments of interface units. With a general objective of regional economic development, their functions include technology transfer in a broad sense, triggering the adaptation and restructuring of universities, government agencies, etc. Most remarkable facts concern the proliferation of organizations, agencies, and other structures tied to innovation and economic restructuring at the regional level. The objective of these structures is to induce the industrial structure to shift towards knowledge-intensive activities. They include different categories of initiatives, such as technology centers, innovation centers, science parks, incubators (or others with similar denomination) aimed at supplying technical, financial, and commercial advice to local entrepreneurs.

2.7.2. The policy development block

The justification for a separate policy subsystem is twofold. First, policy could play a critical role in NSI transition because of the market mechanism's limitations in setting priorities and the need for non-market coordination. Moreover, it is simplistic to assume that policy consists exclusively of a set of exogenously determined tools associated with monetary incentives. Rather these tools are the result of a complex policy process involving the

[5] These separately identifiable blocks of infrastructures would coexist together with those pre-existing elements of infrastructure already attached to the three main sectors (business, public and universities)

above mentioned priorities, the coordinated design and implementation of policies in the various priority areas; and policy evaluations. Therefore, it is appropriate to refer to a policy subsystem involving government bureaucrats, stakeholders, and academic and other experts. It is best in our opinion to consider this subsystem as consisting of a set of institutions capabilities and incentives.[6] The main elements of the policy development subsystem may be summarized as follows:

l. An overall view of tale innovation system, its development through time and its connections with country economic performance.
2. Associated with this is the issue of vision generation through fora/mechanisms/institutions which, through systematic study an interaction among sectors, may lead to a set of long- and medium-term (flexible) objectives and targets for the economy and the country as a whole. This should also be based on a systematic assessment of policy implications of scientific and technological advances.
3. Determination of the salient features of the required industrial, technological, and science policies including their relationship with macroeconomic policies.
4. A coordinated view of the set of major science, technology, and industrial policy areas and their interconnections.
5. A definition of priorities and policy reformulation needs within the various areas and setting mechanisms for implementation.
6. Selection of the policy approach (e.g., extent to which it would be proactive, catalytic, and selective) in each one of the areas considered.
7. Explicit generation of policy capabilities and of the institutional and organizational requirements for the above.
8. Systematic assessment of the implications of other sectoral policies (e.g., fiscal, defense, health, environment, etc.) on the performance of NSI.

In the past, science and technology policy basically entailed planning for the supply of research, largely relying on the autoreferentiality of universities and research organizations. New policy frequently starts from demand, i.e., from an identification of R&D and innovation requirements emerging from the economy and society at large. This requires innovative mechanisms for integrating demand for and supply of R&D. Governmental commissions frequently play a role in defining guidelines for R&D programs, etc., with reference to both demand and supply considerations.

Organizations operating in the policy development block may have different roles: research and study; forecasting and assessment; consultancy; decision-making. They may involve government offices, committees, university institutes, public or independent research institutes, units for technology assessment, and academies and non-governmental organizations with new special roles in S&I policy advice (Ausabel, 1993).

A major task for future work will be to map out the various institutions and mechanisms conforming to this policy subsystem, and then effectively to link them to the restructuring and other transitional trajectory processes taking place within the other blocks of subsystems. For example, vision exercises may lead to a modification of the institutional framework surrounding the creation of new sectorial technological centers; and this may anticipate or follow the restructuring of firms in the productive sector (see Part II). Depending on the parameters of the situation, this may have a significant impact on the nature of the trajectory followed in the new NSI, its completeness, speed, and coherence.

In the next sections we shall attempt to discuss some of these transition issues in a more systematic way. Unfortunately, we will take policy as exogenous rather then derived from processes within the policy development block itself. The objective of fully integrating the policy block into an analysis of the transition to the new NSI is left for future work.

---

[6] Radosevic (1994) has proposed looking at innovation systems in general and at transition problems in Eastern Europe more specific as involving tile three categories of elements inventive, institutions, and capabilities). While we agree, we also believe it useful to view policy development as a subsystem.

PART II

3. Towards a conceptual model of system transition

The model we shall present focuses on two sectors or subsystems (business and university), and aims to present a framework for the systematic discussion of issues in NSI transition (including policy) associated with current paradigmatic shifts in technology and innovation.

Sectors involve or are closely connected with a related infrastructural component. Thus the business subsystem is linked with technology centers (TCs) while the university sector comprises universities (which should be visualized as also comprising public sector laboratories) as well as any type of organization acting as an interface towards the business sector. Policy, which is exogenous, involves either funding/incentives or coordination and institutional change (or the promotion of such change).

We start by defining the NSI building blocks, and provide a characterization of pre-existing (S1) and new (S2) NSI configurations. This characterization is "institutional" rather than technological, and is associated with a particular generic technology (for the latter see Carlsson and Jacobsson, this volume). We therefore do not explicitly touch upon the technological specialization of the business sector nor of its changes. We then verbally describe some critical issues related to the dynamics of system transition, leaving to the final section a broader discussion of analytical and policy implications.

Note that the model presented is far too simple and specific to reflect the situation and the issues confronting any particular country. Nevertheless, its structural elements appear to be sufficiently general to be approximately consistent with the key emerging trends in NSI evolution described in the previous section.

3.1. NSI building blocks

3.1.1. Two systems and their component sectors

As mentioned, the bare bones NSI configuration proposed here is composed of two sectors, business and university, with one or more players or agents in each. System 1 (SI) is relatively closed as far as interaction with the outside world is concerned. While agents may exploit foreign technology and while there is trade with other nations, these are, relatively speaking, weak phenomena as a consequence of protectionist policies on the one hand and (relative) technological stability on the other. The context more or less conforms to the situation facing a number of countries, especially prior to the processes of economic (and political) liberalization during the late 1980s and 1990s, as seen in some Latin American countries, India, and Russia.[7] It may also conform to the reality of the declining mass production paradigm of some of the more advanced countries, but not of all. Under S1 there are no interfacing units and intersectorial links are relatively weak (see Figure 15.1).

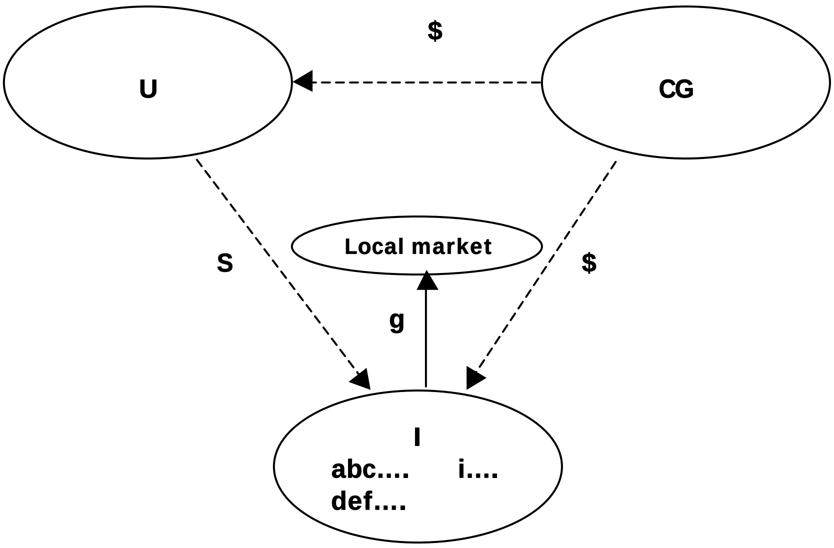
The pressure of changes in the environment, e.g., from economic liberalization, induces a transition from S1 to some configuration of S2. The transition will be more or less successful or more or less complete depending on starting-points and idiosyncratic characteristics of countries.

The eventual complete configuration of S2 (see Figure 15.2) is characterized by a number of features:

l. The system is open, with both the business and the university sectors having numerous connections with the outside world.

2. Interactions between subsystems may take place either directly through industry-university R&D contracts or indirectly through interface units.

[7] For the nature of the system in the former Soviet Union, see Radosevic (this volume).

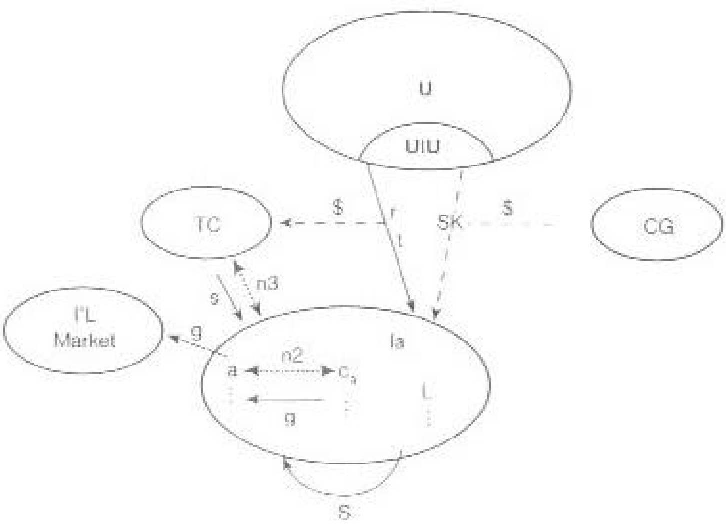


Transactions (g = goods)
Unilateral flows (J = $ = funds or S = skills)

abc...	Firm types, according to product class and size; i = large firms
CG	Central Government
U	University sector
I	Industrial sector

Figure 15.1 System 1 configuration

3. Central to the functioning of the system are techno-economic capabilities, which may also be termed "need-technology coupling capabilities" (Teubal, 1979; Teubal *et al.,* 1991).[8]
4. The presence of interfacing units, i.e., the institutional loci of the above-mentioned capabilities, the role of which is to act as brokers or linking agents for



[8] These are qualitative counterparts to the normal coordinating activity ascribed to the neoclassical ,market since they enable linking supply and demand (more precisely, needs and technology) across (or within) organizations in contexts where neoclassical markets do not operate or do not yet operate, e.g., due to the fact that market building has not yet proceeded sufficiently. Techno-economic capabilities enable a better articulation of user needs and/or a better coupling of technology to needs (a soft function performed by organizations such as "innovation centers"). In our model they will be located within interface units, e.g., technology centers (see below).

g r s t
⟶ Transactions (goods g, services s; research r; training t)

$ S K
- - - - - - - - -→ Unilateral flows (funds $; skills S; technology K)

⟵⟶ Interactions

UIU:	University Interface Unit	a:	SME firm-class
TC:	Technology Center	c_a:	capital goods supplier
		L:	large firms

n2: user - producer networks
n3 TC - business firms networks

Figure 15.2 (Full/complete) System 2 configuration*
* S1 links remaining in S2 are not draw

the improvement of intersectoral links and connections between subsystems and with the outside world.[9]

5. Restructuring of the businesss sector, with the establishment of a variety of formal and informal networks.[10]

In comparing SI and S2 configurations, one should note the differences in types of links connecting agents and sectors. While S1 involves market transactions in goods and unilateral flows in finds and skills, S2 involves also interactions as critical elements in the generation of N2 and N3 networks. Moreover, market-based transactions diversify to include also technological and other services (s-provided by TCs) and research (r); while unilateral transfers also involve technology/knowledge (K). A description and partial analysis of how these additional links evolved in the transition from SI to S2 can be found in section 3.2. In other context interfacing units may be of two kinds:

- Technology Centers (TC), which link industry to the outside world and to the university by providing both soft and hard functions, such as information services and contract R&D, and producing collective goods such as technological capabilities relevant to several firms. The promoting agents of TCs may be the central government, but also new agents (institutions/organizations) entering into an NSI, such as regional authorities, industrial associations, chambers of commerce, etc.
- University Interfacing Units (UIU) is the generic term for institutions or mechanisms established within universities to promote links with the business sector. Since under a full-fledged S2 configuration universities also perform mission-oriented generic research, these units may also evolve to perform some brokerage function in relation to this activity.[11]

Note that the fact that such intermediary structures appear in the system does not necessarily imply that they are effective at accomplishing their-goals.

---

[9] Interfacing units were not really necessary with the more stable and less dynamic technologies prevailing in the previous period when the SI configuration was dominant. The brokerage or linking function may be an essential function in energic markets where techno-economic capabilities are not widely available throughout the population of users and where strong interaction between supply and demand agents is in order.

[10] For a discussion of enterprise restructuring patterns under conditions of technological discontinuities, see Ehrnberg and Jacobsson (this volume).

[11] This certainly has been the case of the very successful interface unit of the Hebrew University (Yissum) e.g., in connection with catalytic processes involving the Casali Institute of Applied Chemistry.

3.1.2. *The business sector*

For simplicity, the business sector is articulated in two subsectors: large firms and SMEs. Both have to undergo significant restructuring and important shifts in their organizational and institutional frameworks to assure a successful transition to S2. Thus, while hierarchical and purely neoclassical market relationships are more predominant under S1, strong intra- and intersectoral interactions and network relationships are essential for the success of the SME industrial subsector in S2.

The above triend follows from the new (potential) possibilities that the changed environment offers small firms to supply value-added, variety products for niche markets (a result of the enormous widening of technological options). Exploiting these requires a restructuring of the SMEs existing under the previous system, both in terms of an enhanced product area focus (specialization, exports) and in terms of networking.

Three types of industrial networks may be schematized within S2 (by adapting from a categorization introduced in Teubal *et al.,* 1991): assembler-component *(NI),* user-supplier (N2), and industry-TC (N3). A successful S2 will involve the coexistence of all three kinds.[12] Large firms may play a crucial role in networking: as systemic assembling companies in NI, materials and plant suppliers in N2, and promoters of TCs in N3. A good real world example which corresponds to our theoretical view of such a sector comprises, among other things, clusters of firms conforming to the so-called industrial district (see Pyke *et al.,* 1990).

Large firms may play a further role by directly supplying to SMEs scientific and technical services through their R&D centers. We assume that market forces are the tigger behind the restructuring of business sector SMEs.

3.1.3. *Generating links with the university sector*

We mentioned that under SI market relationships prevail among firms in the business sector and there are few informational links, interactions, and other non-market links among agents of all sectors including those with industry. More specifically, we assume that under S1 no problem-solving and research liaison of universities with industrial firms is active,[13] while the only link concerne the supply of trained manpower (engineers, scientists, and technicians for production and, to a limited extent, innovation). This is the one-way flow where markets play a certain role (via wage formation, choice of careers by students, etc.) although not an exclusive and probably not the dominant, since universities are public sector institutes with very special systems of governance.

The situation might be drastically different under S2. Large firms will establish frequent direct interaction with universities, through R&D contracts, joint R&D programs and projects, establishment of joint centers of excellence, etc. While small firms have difficulties in connecting with universities, attempts are taking place to lubricate the interface through intermediate organizations, with the generic term of TC, which - among other things - mediates between the two (although links between SMEs and universities may be quite indirect). On the other hand, university interface units (UIU) may promote direct links with both large and small firms.

The transition, however, is not only the result of the appearance of new technologies which open up new opportunities for university staff (e.g., in biotechnology or optoelectronics) or of the emergence of more mission-oriented generic research areas in applied science an engineering. No less important are the changes in the systems of governance within the universities, particularly those enabling and providing incentives to academic staff to perform work for outside customers; and those assuring a reasonable measure of secrecy to the proprietary knowledge being produced. Moreover, explicit decisions have to be taken concerning interfacing units and joint university-industry R&D programs. The upshot is that numerous potential links, both in the form of transactions and of unidirectional flows or interactions, may develop between the university and business

[12] A fourth type of network (the horizontal network) connects firms in a sector by means of their shared experiences and collective searches for new technologies and markets. Despite the importance of N1 networks for a refined System 2 we ignore it at this stage in our work.

[13] For simplicity we ignore possible S1 links derived from the problem-solving activities of practically oriented or technology oriented universities such as those existing in US universities during the nineteenth century (Rosenberg and Nelson, 1992). The enormous increase in links between US universities and industry since the mid-1980s is, however, broadly consistent with our S2 view of the matter.

sectors. Given the external developments in science and research a critical factor is change in the institutional framework within universities and in their systems of governance.[14]

3.2. Dynamics of the transition

3.2.1. Institutional change: anticipatory and endogenous

As illustrated above, the transition to S2 may be facilitated by fundamental changes in the institutional framework which simulate the development of both interfacing and infrastructural organizations, thereby enabling greater system connectivity. For example, institutionai changes and emerging UlU may enable direct R&D links with firms. Firms may thus fund generic research at universities and may form consortia among themselves and with universities. The links with small firms, if developed, may also be mediated by the TC or the UIU.

Some changes in institutions and governance - especially the more informal ones may be considered as demand-pull or bottom-up solutions of atomistic agents to the new problems emerging from changes in the environment. [15]Network relationships might arise, for example, when an innovative supplier of capital goods - in view of the new possibilities of variety-cum-incremental-improvements offered by the new IT - experiments with becoming a network entrepreneur, and eventually succeeds in providing a network configuration to the enhanced user-supplier interactions required. However, successful responses of this kind are not automatic so outcomes vary from case to case.

The generation of new links and the restructuring of existing organizations may depend on prior explicit attempts at coordination; adapting formal and informal institutions; catalytic incentives for the creation of collective organizations and interface units; and associated techno-economic capabilities. Vision exercises or strategic policy formulation exercises may trigger these anticipatory institutional changes (AIC), which are necessary for a successful transition to the new S2 configuration.[16]

The distinction between endogenous and anticipatory institutional changes is related to the distinctions among the various processes of institutional change or selection mechanisms for institutions mentioned by Nelson: the market, professional, and politic mechanisms. To these we may add the bureaucratic mechanisms which would operate within the context of a given policy and policy subsystem. Thus market mechanisms might lead to endogenous institutional development where needs are pretty much focused on those of the relevant, immediate subsystem. On the other hand, anticipatory changes in institutions may be the result of professional bureaucratic, and even political mechanisms rather than of market or purely market-based mechanisms. These would be anticipatory since the overall needs of the system could - given suitable vision policies and coordination efforts - be detected earlier by such non-market agents than by market agents active in a particular subsystem. They may induce all intensification of the activities generating or responding to these more localized needs.[17]

3.2.2. Nested subsystems and transition trajectories[18]

In our model a subsystem is built around particular core sector and may include a related element of the new infrastructure. It includes both players and intra- and intersectoral links. The core sector (and possibly its linking with the infrastructure element) is the locus of the novel restructuring activity propelling NSI transition at a

[14] A critical factor similating desired institutional change within universities could be an overhaul of the system of financing universities. The emergence of a mechanism for selective support of mission-oriented, generic research programs as well as various university-industry link programs may accelerate such developments.

[15] Nelson (1994) quotes the work of sociologists studying the development of industrial organizations (or extra-industry supporting organizations) including formal ones such as industry and trade associations. These deal with the establishment of product or technical standards, relationships with government, and the provision of public goods more generally (our addition). These developments are described as part of the co-evolution of firms, technologies, and organizations. As such they are first and foremost part of the purely endogenous component of the process of organizational change. Note that the consolidation of patterns of interaction between or across firms and between firms, customers, and suppliers are also important aspects of this process.

[16] We will use the term AIC to include anticipate institutional changes; stimulation of related collective intermediate organizations; and initial stimulation of relevant technological and techno-economic capabilities.

[17] Thus the creation of UIU and the facilitation of links between the university sector and industry may articulate the (localized) needs of the industry subsystem, i.e., may take place before a successful restructuring of industry has increased demand for new types of graduates and for university research. This paving the way for the supply of future needs may in turn, via expectations of forward-looking entrepreneurs within industry, increase the pace of restructuring in this sector.

[18] In this section we focus exclusively on the SME segment of the business sector. Both SMEs and large firms will be considered in 3.2.3.

particular phase. The notion of subsystem is useful if it enables us to breakdown an analysis of system transition into phases, thus contributing to understanding the whole. In our case we define a set of nested subsystems rather than a set of non-overlapping ones, and this may be done in a way that corresponds to a reasonable sequence of phases in the transition towards S2. The nested subsystem structure reflects the fact that even if the locus of restructuring shifts from the first to the second NSI sector, a deepening of the process continues in the (first) sector with which system transition began.

We define an endogenous (or pure demand pull) transition trajectory is one comprising a number of partially consecutive but yet overlapping phases starting with a focus on the endogenous, entrepreneur-led restructuring within the industrial sector of SI (Phase I); followed by the spreading of change beyond the sector towards the creation of TCs and N3 networking (Phase 2); and ending with the generation of interfacing units at the university sector and associated links connecting this sector with firms and TCs (Phase 3). A natural correspondence with this trajectory is a set of three nested subsystems:

- SubA: the firms of the industrial sector (the core sector) which are at various stages of restructuring including the emergence and development of user-producer networks and links with world markets and other sectors;
- SubB: the former plus the TC (the core element) and its links both with firms (N3) and with other sectors;
- SubC: the subsystem formed by SubB and the university sector (which would be the core sector) together with the links of this sector.

The set of subsystems forms a hierarchy involving both lower and higher level elements and this corresponds with the various phases in the above-mentioned transition trajectory. Thus at Phase 1 the major system building or system transition activities which are qualitatively novel take place at the core of SubA which is the lower level subsystem of the hierarchy; while at Phase 3 they will be taking place at the core of SubC which is the higher level one. Throughout the phases, however, system building (or the transition from S1 to S2) also takes place beyond the corresponding core sector, more specifically at lower level subsystems. Thus, while in Phase 2 the focus of qualitatively novel system transition activity lies at the TC and its links with industry (SubB), this coexists with a continuation of the restructuring activity previously initiated within SubA, i.e., a continuation of the restructuring and networking occurring within industry (see Table 15.1).[19]

In the real world other more complex and mixed transition trajectories will exist. An important class involves endogenous changes in institutions together with significant anticipatory changes in the institutional framework associated with a higher level subsystem. These trajectories might be underpinned by explicit vision exercises promoted or triggered by the government and other major actors. For example, while entrepreneurs are only beginning to network within SubA so the need for institutional adaptations *vis-à-vis* TCs (SubB level) is not yet strongly or sharply felt, government policy, based on its anticipating future needs, is already providing the institutional underpinning for and catalytically supporting the creition of TCs. More generally, while the market is pursuing restructuring at the early NSI transition phases (i.e., focused on lower level subsystems), non-market processes (bureaucratic, political) may lead to actions involving significant institutional changes at higher level subsystems within the NSI hierarchy. In our model these might

[19] Along with market forces and endogenous co-evolution between industry, technology, and institutions a predominantly endogenous transition trajectory may include a smattering of government-sponsored enabling changes in institutions (as an aspect of government policy). Such changes are not considered to violate the fundamental endogenous or demand-pull nature of the transition process given the dominant position of market forces and of endogenous co-evolutionary processes of institutional change.

Table 15.1 *NSI transition trajectories: phases, activities, and subsystems*

Phase	Activity and locus of NSI restructuring	Subsystem
1	Specialization and networking of SME segment of industry(I)	SubA = I*
2	Creation of technology centers (TCs) and N3 Networking (and continuation of I-sector restructuring	SubB = I+TC* (+links)
3	Creation of university interface units (UIU) and emergence of new U-I links (+ continuation of I-Sector restructuring and N3-networking)	SubC = I + TC + U* (+ links)

* "Core" sector of subsystem.
I = Business sector; TC = technology center; U = universities.

include legislation and support concerning industry associations, and the creation of an appropriate institutional framework governing future links between TCs, universities and industry.
Table 15.2 illustrates a possible mix between endogenous and anticipatory institutional change. It must be stated that these actions not only unlock obstacles endangering the future take-off and future growth of SMEs (and other firms) in world markets: they also positively affect the current restructuring efforts of these firms.
The reasons for this are complex; we will mention only two. The first is that very early in the restructuring process of SMEs, entrepreneurs are not yet fully aware or

Table 15.2 *A "Mixed" NSI transition trajectory: types of institutional change*

Type of Institutional Change Phase	"Endogenous" is (e.g. market-led)	"Anticipatory" (bureaucratic or political)
1		• Legal and institutional framework enabling the creation of technology centers (TCs)* • Coordination and ioint public/private planning leading to establishment of TCs • Catalytic stimulation of initial TC capabilities (technological and techno-economic)
2	• Stimulation of N3 creation and development • Experience-led adaptions of the TC institutional and policy framework	• Legal and institutional framework allowing university researchers to link with industry • Creation and operation of university interface units • Catalytic stimulation of initial university-industry "coupling" capabilities
3	• Further coordination and experience-induced institutional adaptations to facilities growth of U-I links	

* Following Romer (1993), this could include legislation assuring imposition (under certain conditions) to finance (industry specific) generic research, training, and technological development of a tax or levy on an industrial sector.

capable of articulating their needs for sophisticated technological services and even firm-based R&D (see Teubal, 1979; and Teubal *et al.,* 1991). Second, even when having become aware of these needs, there are still delays in identifying the necessity for collective action and the associated institutional requirements. A broad view of the emerging system such as that generated by government through, e.g., foresight or other vision exercises - may enable an earlier identification of the broad category of new needs and a clear anticipation of the changes in institutions and systems of governance required to satisfy them (e.g., the need of collective action to supply public goods). Moreover, forward-looking entrepreneurs will positively respond to this anticipatory action of government by accelerating their process of change (since they foresee fewer supply bottlenecks throughout their projected growth path). Less forward-looking entrepreneurs will also restructure their firms faster than other-wise due to the earlier availability of sophisticated inputs and services (even before their need is materialized or translated into actual demand). Their response, however, is likely to be a delayed and much slower one than that of the previous group of entrepreneurs, since the latter's response is also based on expectations.
The upshot is that AICs may considerably enhance the probabilitv of successful restructuring of the SME industrial sector's networking and integration in world markets. More specifically, performance at the critical SubA level which reflects the system's initial pressure to changes - may critically depend on anticipatory/exogenous changes occurring at higher level subsystems.
Notice that the above mix between anticipatory and endogenous changes highlights the broader systemic connections within the system. Thus the earlier the transition to SubB level, the greater the reinforcement of the change taking place at SubA level. [20]

3.2.3. Description of a complete NSI transition

We will now describe a full transition to S2 based on a mixed trajectory. As stated above this might require less than drastic changes in the environment, in addition to vigorous, autonomous restructuring of the industrial sector and timely AIC. We make no claim that this transition corresponds to a real world situation. It is one within a set of possible transitions that may occur within the stated S1 and S2 configurations. A variety of transitions may exist because (1) transitions need not be complete, i.e., they may lose momentum and truncated; and (2) the sequence of stages and the stages themselves, which connect S1 and S2, may differ from those presented below. Moreover, chance and small historical events (Arthur, 1988) may have very significant effects on trajectories.[21] The objective is to illuminate the sort of systemic policy issues which are likely to emerge when (discussing system transition.
The three transition phases of Table 15.2 are now described and subsequently traced in Figure 15.3 where the restructuring or system transition for each phase is shown. No distinction will be made in the figure between the coordinating function of government and changes in the institutional framework.

Phase 1: Autonomous industrial restructuring (SubA level - black)

1.1. Emerging (and vigorous) specialization and networking of enterprises in the business sector.

1.2. First expansion into international markets and associated demand for quality technological services and R&D provided by TCs (see DI in Figure 15.3).

[20] The criticality of AICs pertaining to higher level subsystems and of mixed transition trajectories depends on the strength of changes in the environment relative to the energy and farsightedness of industrial entrepreneurs. Thus when changes in the environment are drastic, a purely endogenous trajectory may not suffice, i.e., a mix of endogenous and anticipatory adjustments would be necessary. Horizontal technology policy incentives (Teubal, 1995) directed to business firms may enhance the probability of successful SubA restructuring.
[21] Needless to say, in even more important source of diversity in transition paths is differences in the initial S1 and the final or ideal S2, e.g., the transition paths for small economies will very likely substantially differ from those of larger economies. Such an analysis of alternative transition trajectories, while potentially very rich goes beyond the scope of this chapter.

Phase 2: Technological services provided by TCs (SubB level, but also affecting SubA - dark gray)

2.1. Government coordinates and provides incentives for establishing a TC.

2.2. The TC starts providing services.

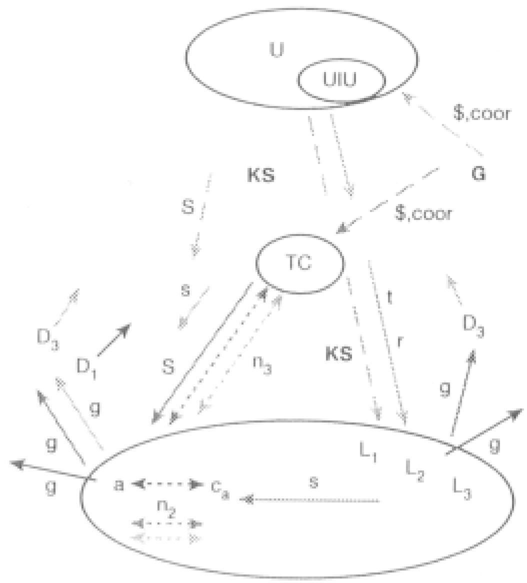


Figure 15.3 Transition phases*

* The same notation as in Figure 15.2 is used: "coor" represents Government coordination efforts which go together with monetary incentives ($). Black arrows correspond to phase 1; dark gray ones to phase 2; and light gray ones to phase 3.

2.3. The TC acting as a network entrepreneur successfully creates an N3 network linking it with business firms.
2.4. The resultant enhanced activity of the TC reinforces both N2 and corresponding expansion of SMEs into international markets.
2.5. Large firms provide research and technical services to SMEs.

Phase 3: University supply of (specific) research and manpower to industry (SubC also affecting SubA - light gray)

3.1. Firm expansion enhances demand for technological manpower, services, and research supplied by universities (D3 in Figure 15.3).
3.2. Demand pressures together with incentives (and pressures) from government bring about changes in governance/institutions within universities with the creation of UIU.
3.3. Establishment of R&D links with large firms and training in new technical specialities for all firms.[22]
3.4. Firms receive new specialized manpower from universities which sustains their expansion and penetration of world markets.
3.5. The above reinforces TC-service provision and industry restructuring.

An interesting point is the intertemporal intertwining of both supply and demand elements when explaining system evolution. Thus, successes of industrial firms in the initial restructuring efforts lead to increased demand for specialized manpower from universities and to increased demand for research. These events underlie the

[22] Contrast Sweden's university system with the relatively low demonstrated flexibility of its universities in restructuring training patterns of electronic engineering (private communication with Bo Carlsson) with Israel's university system, which has demonstrated ample flexibility in the training of computer scientists (Justman and Teubal, 1988).

subsequent stage of changed governance at universities (which should also be interpreted as an expression of the new roles to be played by the university sector in sustaining the momentum of industrial expansion). The supply response to these new needs is multipronged: enabling regular research links between a firm and university researchers; and, rather implicitly in the model, greater market responsiveness of university training efforts (e.g., greater emphasis on electronics and computer science/engineering). Supply responses take time and generally require adaptations in the institutional framework. When these are successful and timely they will stimulate restructuring and thereby reinforce demand at lower level subsystems. Note that timeliness may require that the institutional adaptation be of an anticipatory nature.

4. Summary and implications of the analysis

In the first part of this chapter we attempted to summarize the salient features of the current techno-economic paradigm and its implications for national systems of innovation. We conclude with a relatively detailed discussion of NSI building blocks and restructuring trends in the university, public, and business sectors, as well as a discussion of new infrastructural components that may play, a significant role in propelling the current evolution of NSIs. One objective of Part I was to present a basis for a more conceptual and abstract discussion of the NSI transition in Part II. The appreciative theory exercise or model of section 3 is a structuralist and institutionalist version of an evolutionary model. It develops one possible configuration for an NSI and its transition, and focuses on what may be termed a complete transition to a fully new NSI configuration (one which is adapted to the new techno-economic paradigm). While its purpose is fundamentally illustrative, methodological, and directed to set the policy discussion within a broader context than that which is usual, it certainly does not necessarily represent a specific real world transition. Part I, however, shows that the components of such a model and the characteristics of the transition are to some extent grounded in reality. Unfortunately, a systematic discussion of conditions leading to partial, truncated transitions (and of lock-in phenomena more generally) goes beyond the scope of this chapter. It will eventually require the development of a full-fledged analytical model.

The model of NSI transition and systemic effects

The modeling strategy involves first defining an old NSI (SI) and a new NSI (S2) adapted to the new paradigm, i.e., with greater complexity in terms both of components (TCs, UIUs) and links.[23] Second, it looks at the transition process from S1 to S2. The pressure to change in our model comes from enterprises of the business sector but government may spur change in an anticipatory fashion by promoting institutional change and by providing catalytic support to the emergence of intermediate organizations. It can also directly help enterprise restructuring, e.g., through a horizontal technology policy (a possibility not discussed in this chapter). All cases involve a TI-assisted process of change rather than a TI-led process.

Whatever the relative roles of market forces and government policy (and this might depend on the strength and vitality of the former), a successful transition of NSIs is associated with considerable institutional change.[24] A major objective of institutional change and of the new infrastructure components is to bring about enhanced links within the system - including market links (see market building below). Interesting aspects, are the connections in the evolution of the various types of links, both those that are and are not explicitly considered by our conceptual model. Thus, for-example, starting provision of technological services from the technological center (TC) to firms may eventually lead to a situation dominated by full-fledged, market-based transactions. These together with the associated networking (N3) may create interaction, information exchange, and coordination conditions for successful TC-adoption of industry relevant technologies and technological capabilities. These in turn may set the base for subsequent unilateral flows from (or externalities provided by) TCs to industrial firms - in the form of technological knowledge, personnel spin-offs, and capability transfers flowing from the new technological assets of the organization.

The verbal modeling exercise focuses on one type of TI-assisted transition trajectory which leads S1 to S2 (a complete trajectory). As mentioned, the possibility of truncated or partial and perverse or incoherent

[23] The assumption of a given S2 is a necessary simplification that helps us to focus on a subclass of a relatively well-defined NSI transition. A full evolutionary perspective would have to consider a situation where the nature of the S2 set will gradually emerge during transition.

[24] A related example of institutional changes endogenously induced by the (cooperative rather than purely atomistic) action of market forces are the self-organizing industrial boards proposed by Romer (1993). Their implementation, however, may require prior institutional adaptation, e.g., imposing an industry-specific tax. Thus timely government policy may be critical even in this case.

trajectories, while referred to, has not yet been explicitly analyzed in a systematic way. [25]The actual transition trajectory analyzed involves three main phases which highlight both the connections between early and later changes in the system, and the mutual reinforcement derived from changes at different parts of the system. Some connections involve sectors that are quite distant from one another in time and space, e.g., the early effect of enterprise restructuring in the business sector on the contribution of universities to reinforce the success of these firms via the future provision (and expectations) of sophisticated services and industry-relevant research. The systemic nature of these effects has been clarified by the introduction of a hierarchy of nested subsystems.

Thus anticipatory institutional changes (AICS) at higher subsystem levels reinforce the restructuring occurring at lower subsystem levels and reduce the critical level of effort required for success at such lower levels. The possibility arises that in some cases it may be necessary to act far from the current focus of action in order to succeed at the early stages of the transition process.[26]

Role of AIC

The model suggests that institutions play two types of roles in successful NSI transitions: an enabling role and a proactive role. The enabling role results in a successful concatenation of demand and supply, e.g., successful restructuring of industrial entrepreneurs enhances the demand for quality technological services, while changes in the institutional framework and the stimulation of a TC enables a corresponding supply agent to emerge. This will strengthen restructuring. The proactive role of government in promoting institutional change in the above example takes the form of strengthening the original industrial restructuring and demand creation process itself and thereby contributing to its success. Thus, by anticipating the actual demand for quality services, government - in parallel to the initial restructuring efforts of firms - undertakes actions leading to changes in institutions. Actual demands may be weak but knowledge that future demands will be promptly met may spur entrepreneurs in their restructuring efforts. The effect will be a positive reinforcement of initial NSI transition due not only to an earlier supply response but also to the strengthening of demand. This of course requires a systems view of NSI transition, the generation of which is, in our opinion, a major task of policy.

The above suggests the importance of designing and implementing policies that encompass not only the current "locus of action"' but also those which, a priori, seem to be removed from it. Success in this may lead to a virtuous cycle of NSI evolution and to a complete transition to S2. It may also reduce transition times as well as assure "homing" into an appropriate trajectory. Alternatively, absence of such policies may truncate the transition process - especially if initial restructuring efforts are weak - and may even lead to a vicious cycle. Note that coordination of the various policy instruments or of the various policies or policy areas, becomes a major issue in the overall policy framework for NSI transition.

AIC links with market building and diffusion policies

In our model a successful trajectory is associated with two features: primarily the generation of relatively well-functioning markets in technological services which will absorb the outputs of a new infrastructural component (a TC) and to a certain extent, those of the large firm segment of the business sector: and, partially, with university research and (specific) training. In both cases the user is the business sector, the prime agent in the restructuring process (SMEs in the case of technological services; large firms in the case of university research and training). Market building is an outcome of both the enabling and the proactive roles of institutional change and as such can be viewed as necessary for successful NSI transition.

We now summerize what our conceptual framework presumes in this regard and suggest additional thoughts on what may be called diffusion policies (since market building may be central means to assure successful diffusion

[25] The processes involved in such a complete trajectory are not exclusively market processes although the initial trigger for system change has been assumed to come from the restructuring efforts of industrial firms. In our model exclusive reliance on the market may lead to locked in, truncated, or perverse trajectories.

[26] Despite the potential importance of AICs at Phase 1, it is likely that some initial, autonomous industrial restructuring should take place by firms in order to identify the desired changes in the institutional framework. These autonomous changes may also be important for registering short-term social benefits and to generate awareness of the need and direction of change. The upshot might be a virtuous cycle in at least two interested senses: early restructuring success triggers favorable policies which are in themselves success reinforcing; and early changes at SubA level trigger changes at higher level subsystems which, in turn, reinforce the former changes.

of technology). To sharpen our discussion in what follows we focus exclusively on market building for technological services mediated by an intermediate organization which is oriented to SMES.[27]
The situation facing SMEs *vis-à-vis*, new technology involves (to varying degrees) the following elements:

- needs are widespread but weakly determined in terms of the new technology which adds to absence of technological capabilities;
- demand articulation or need determination through interactive learning (Lundvall, 1985; Teubal 1979) is collective learning process of users (the SMES);
- due to economies of scope, the supply of the relevant technology necessitates a collective effort of investment in new capabilities;
- effective capabilities for need satisfaction are not only "technological" but "techno-economic". They are acquired through experience in providing the technological service or transferring the technology to users.

Given the above situation, the role of government in AIC includes:

- creating the institutional framework for the collective supply of such capabilities and technologies (e.g., Romer's legislation on imposing a levy or tax on firms of a sector to finance training and generic research);
- stimulating the emergence of bridging organizations like innovation centers involved in soft activities such as diagnosis and referral to experts and technological centers (involving both soft and hard functions);
- catalytic support of initial capability generation, i.e., incentives to finance transfer of the technology to, and its absorption by, the intermediate organization. Catalytic support would also include underwriting "initial diffusion" which, in our context means initial, experimental implementation of the service provision or technology transfer activities which will help users to "articulate demand". It will also add "techno-economic" capabilities to suppliers and thereby assure a more automatic and demand driven diffusion of technology at a subsequent stage.

The nature of the support is not supply push - but rather a combination of this with demand pull. In fact, the catalytical support focuses no less on articulating the needs of an initial class of users than on creating technological capabilities per se. 'There is an assumption of success in the collective process of identifying SME-relevant capabilities (this may not be so difficult due to success abroad in utilization of such technologies). The outcome of the four steps outlined above will be the triggering of an automatic, demand-driven, process of diffusion of the recently absorbed technologies among the wider universe of SMES. Government support, in line with the catalytic approach, will then continuously decline through time.
It follows from the above that simply establishing (or stimulating the establishment) a TC is not enough for success. There are at least two additional conditions: the government agency successfully identifies "relevant" technological capabilities and types of service needed; and these capabilities are generated and applied with an entrepreneurial attitude (i.e., a proactive policy of going to firms, attempting to understand their needs, and articulating these in terms of desired service configurations). Finally, additional steps may have to be taken to assure diffusion of demand for new technologies or technological services to a wider set of users. For all of these reasons, the design and implementation of an AIC may be more or less successful in propelling the desired NSI transition. It is no panacea and it may, and has, frequently failed. It does remain, however, a critical component of successful transition policy.

[27] Technological services are assumed to flow from existing rather than from radically new technologies, although they may be new to the SME sector undergoing the NSI transition.

References

Arthur, B. (1988) Competing technologies, increasing returns and lock-in b historically small events. *Economic Journal,* 99, 116-33.

Ausabel, J. (1993) The organizational ecology of science advice in America. *European Review, 1* (3), 249-61.

Carlsson, B. (1992) Technological systems and economic development potential: four Swedish case studies. Case Western Reserve University.

Cohen, W. R., Florida, R. and Coe, W. R. (1994) University-industry research centers in the United States. Carnegie Mellon University, typescript, July.

David, P. and Foray, D. (1994) *Accessing and Expanding the Science and Technology Knowledge-base: A Framework for Interpreting Available Quantitative Measures.* Organization For Economic Cooperation and Development, Division of Science, Technology and Industry. Paris: OECD.

European Research Management Association (ERMA) (1989) Co-operative R&D in Industry. Working Group Report no. 38. Paris: ERMA.

Foray, D. (1993) Technological creativity and the wealth of the European periphery: who will hold the torch in the Next Century, Santiago de Compostela, Spain, September.

Freeman, C. (1987) *Technology Policy and Economic Performance. Lessons from Japan.* London: Pinter.

Freeman, C. and Perez, (1988) Structural crisis of adjustment: business cycles and investment behaviour. In G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (eds), *Technical Change and Economic Theory.* London: Pinter.

Galli, R. (1992) Structural and institutional adjustments and the new technological cycle. *Futures,* October.

Hirschman, A. (1956) *Strategy of Economic Development.* New Haven, CT: Yale University Press.

Imai, K., Nonaka, I. and Takeuchi, H. (1988) Managing the new product development process: how Japanese companies learn and unlearn. In K. Clark, R. Hayes and C. Lorenz (eds), *The Uneasy Alliance: Managing the Productivity-Technology Dilemma.* Cambridge, MA: Harvard Business School Press.

Justman, M. and Teubal, M. (1988) A framework for an explicit industry and technology policy for Israel and some specific proposals. In C. Freeman and B.-A. Lundvall (eds), *Small countries Facing the Technological Revolution.* London: Pinter.

Justman, M. and Teubal, M. (1995) Technological infrastructure policy (TIP): creating capabilities and building markets. *Research Policy* 24, April, 259-81.

Lundvall, B. –A. (1985) *Product innovation and User-Producer Interaction.* Aalborg: Aalborg University Press.

Lundvall, B. –A. (ed.) (1992) *National Systems of Innovation – Towrard a Thoery of Innovation and Interactive Learning.* London: Pinter.

Malerba, F. (1993) The national system of innovation: Italy. In R. Nelson (ed.), *National Innovation Systems: A Comparative Analysis*. New York: Oxford University Press.

Nelson, R. (1987) Roles of government in a mixed economy. *Journal of Policy Analysis and Policy,* 6 (4), 541-57.

Nelson, R. (1993) *National Systems of Innovation.* Oxford: Oxford University Press.

Nelson, R. (1994) Recent evolutionary theorising about economic change. In N. Smelser and R. Swedberg (eds), *Handbook of Economic Sociology.* Princeton: Princeton University Press.

North, D. (1994) Economic performance through time. *American Economic Review,* 84 (3).

Organization for Economic Cooperation and Development (OECD) (1988) *Science and Technology Policy Outlook.* Paris: OECD.

Piore, M. and Sabel, C. (1984) *The Second Industrial Divide.* New York: Basic Books.

Pyke, F., Becattini, G. and Sengenberger, S. (1990) *Industrial Districts and Inter-Firm Cooperation in Italy*. Geneva: International Institute for Labor Studies.

Radosevic, S. (1994) Strategic technology policy in Eastern Europe. *Economic Systems,* 18 (2), 87-116.

Romer, P. (1993) Implementing a national technology strategy with self-organizing industry investment boards. *Brookings Papers on Microeconomics,* 2, 345-99.

Rosenberg, N. and Nelson, R. (1992) American universities an technical advance in industry. Typescript.

Scitovsky, T. (1963) Two concepts of external economies. In A. Agarwala and S. Singh (eds), *The Economics of Underdevelopment.* Bombay: Oxford University Press.

Strategic Program for Innovation and Technology Transfer (SPRINT) (1994) *The future of Research and Technology Organisations in Europe.* European Commission, Report EUR 15458.

Tassey, G. (1991) The functions of technology infrastructure in a competitive economy. *Research Policy,* 20, 345-61.

Tecce, D. (1992) Competition, cooperation and innovation – organisational arrangements for regimes of rapid technological progress. *Journal of Economic Behavior and Organisation,* 18, 1-25.

Teubal, M. (1979) On user needs and need determination: aspects of the theory of technological innovation. In M. Baker (ed.), *Industrial Innovation: Technology, Policy and Diffusion.* London: Macmillan.
Teubal, M. (1996) R&D and technology policy at NICs as learning processes. *World Development,* 24 (3), 449-60.
Teubal, M., Yinnon T. and Zuscovitch, E. (1991) Networks and market creation. *Research Policy,* 20, 381-92.
Teubner, G. (1990) Unitas multiplex: la nuova decentralizzazione dei gruppi di imprese. *Impresa e Stato,* September, 18-28.
Willinger, M. and Zuscovitch, E. (1988) The economics of innovation intensive production systems. In G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (eds), *Technical Change and Economic Theory.* London: Pinter.
Womak, J., Jones, D. and Rows, D. (1990) *The Machine that Changed the World.* New York: Rawson Associates.
World Bank (1992) *The East Asiatic Miracle: Economic Growth and Public Policy.* New York: Oxford University Press.