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# A Theories-Based Systemic Framework for Evaluating Diverse Portfolios of Scientific Work, Part 1: Micro and Meso Indicators

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**Abstract**

*Recently, several articles have argued for changes in the kinds of evaluation being conducted for research, technology, and development (RTD) programs. Among other suggestions, these are of special merit: (1) a more macro and systemic focus, (2) concentrating on the processes of generating innovation, (3) using theory to guide the RTD evaluation, and (4) identifying blockages and obstacles. The authors put forth a multilevel, theories-based framework of indicators for RTD evaluations that addresses these suggestions and is a guide for policy makers in policy formulation and reformulation.* © Wiley Periodicals, Inc.

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Recently, several articles (Arnold, 2004; Molas-Gallart & Davies, 2006) have appeared arguing for changes in the kinds of evaluation being made of research, technology, and development (RTD) programs. Among other suggestions, four seem to be of special merit: (1) a more macro and systemic focus, (2) greater concentration on the processes of generating innovation, (3) using theory to guide the RTD evaluation, and (4) identifying blockages and obstacles or what Arnold (2004) labels "failures." To this list of suggested changes, we would add that RTD evaluations must investigate key indicators to generate data that policy makers need in order to know what policy *re*formulations should be made and how.

These recent concerns about the structure of evaluations stem from a number of challenges that governments face today. In particular, we argue that three primary factors—the rising level of RTD expenditure in real terms, the importance of innovation for both economic and noneconomic goals, and the increasing speed of development of innovative solutions—significantly increase the need for evaluations that better guide government policy formation and *re*formulation.

The objective of this chapter is to outline a theories-based Innovation Systems Framework (ISF) of indicators for RTD evaluations that can aid government policy makers in policy formulation and *re*formulation. The indicators that are proposed suggest protocols for performance monitoring and evaluation; they could form the basis of a new kind of data structure for science reporting agencies such as the National Science Foundation (NSF). Although the ISF we have developed is multilevel in nature, this chapter focuses on the micro- and meso-analytical levels. We address the issue of macro indicators and their relationship to the micro and meso elsewhere (Jordan, Hage, & Mote, 2007). The systemic framework we suggest has significant potential for developing socioeconometric models that incorporate the innovation processes necessary for predicting innovation outcomes (or throughput), a request recently made by John Marburger (2005), the director of the U.S. Office of Science and Technology.

Central to this is the idea of innovation network theory (Hage & Hollingsworth, 2000), which describes the innovation processes and identifies a number of potential blockages in the connectedness of innovation networks in technology sectors or regimes. The theory argues that there are six research arenas in the process of innovation (basic, applied, development, manufacturing, quality, and commercialization research) and the linkages among these arenas are critical for continued innovation. In our framework, the meso level connects to the micro level that encompasses Jordan's theory of profiles (2006) and previous work on industrial innovation (Hage, 1999), and it offers a larger context for discussing potential organizational obstacles to innovation. The meso level permits focus when connecting to the macro level, encompassing the various institutional theories in the national system of innovation literature (Hall & Soskice, 2001; Nelson, 1993) and the new work on institutional change (Campbell, 2004),

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as well as permitting discussions of obstacles to innovation created by various institutional rules.

Together, the three levels answer a plea for a theory of knowledge production that contains these three analytical levels (Hage & Meeus, 2006) and creates an opportunity for contributing to other theories and frameworks such as organizational learning, knowledge communities, and for putting the throughput or black box of RTD into standard econometric input-output evaluation models.

Within each analytical level, we identify three sets of indicators that provide guidance for policy makers, as well as indicate specific possible blockages and obstacles. In general, micro indicators focus on how to allocate funds using the criterion of balanced investments (public-private) across the six RTD arenas in a technological sector, across the portfolio of investments within each arena, and across selected research organizations with the appropriate organizational profiles for the portfolio choices. Similarly, meso-level indicators measure the outputs of each arena in real time, the strength of the connectedness between differentiated arenas, and the overall assessment of innovation performance including societal impact.

## A Theories-Led Innovation Systems Framework for RTD Evaluation

As Weiss (1997) discusses, a theory-based evaluation allows one to address the most relevant mechanisms that mediate between processes and outcomes and better understand how programs work. A particularly useful way of capturing the complexity of the innovation process from scientific advance to socioeconomic outcomes is contained in the idea innovation network theory of Hage and Hollingsworth (2000). The idea innovation network starts with a simple idea, namely that in many technological sectors (especially the more high-tech ones) commercially viable product innovations necessitate research in the six arenas diagrammed in Figure 1.1. The theory builds on the conceptual nonlinear model of Kline and Rosenberg (1986) but alters the focus to arenas within a technological sector, and it adds the concept of quality research to the original five areas.

Why be concerned about all six arenas in the innovation process? The process of generating scientific advance and innovation in products or processes that have socioeconomic impact can be thought of as "throughput." The idea innovation network theory presents a necessarily complex view of the throughput of the innovation process and does so at the meso-technological-sector level, where indicators and socioeconometric models of innovative performance can be constructed. Another advantage of this theory is that it can expose research "gaps" (Marburger, 2005). Some of these arenas have been ignored, with detrimental consequences for the competitive position of certain countries. These arenas include quality control research in the sense of fewer defects and lower operating costs, but also

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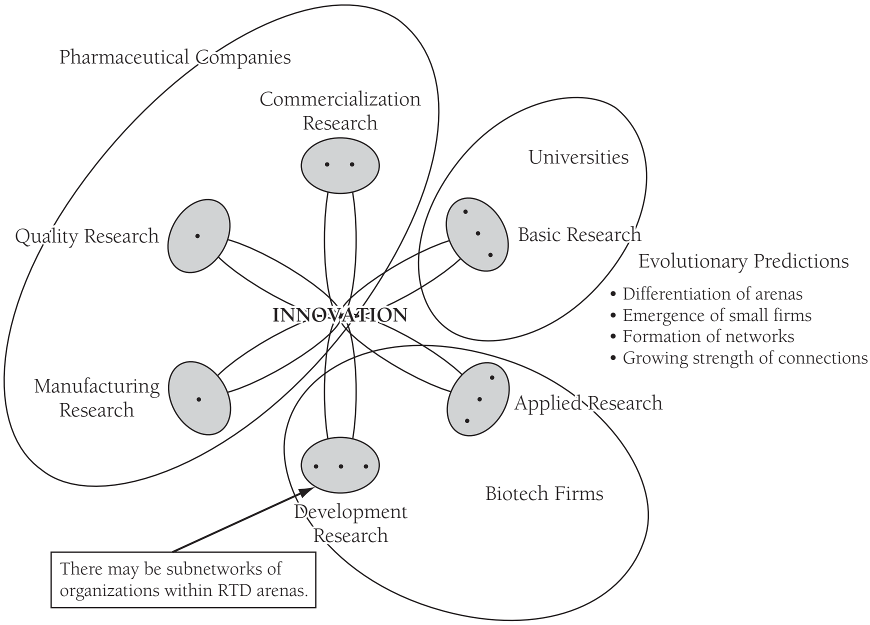
**Figure 1.1. An Example of the Evolutionary Predictions in the Idea Innovation Network Theory: Biotech/Pharmaceutical Sector**




research that reduces the various externalities of the products such as energy consumption, global warming, and health risks. The importance stems from three considerations: (1) reducing costs, and potentially the export of jobs to developing countries, (2) increasing customization so that multiple products can be produced on the same assembly line, and (3) reducing externalities.

Consistent with Kline and Rosenberg (1986), a good idea for an innovative product or service can start in any one of these six arenas. The process of innovation is nonlinear, with ideas moving back and forth between arenas multiple times; hence use of the word *network* rather than chain. The real meaning of the term *network* is the argument that each of these arenas must be connected, and if one of the arenas has a radical advance in knowledge it must be strongly connected to the other arenas for transfer of the tacit knowledge involved in the radical knowledge advance. Strong connections are defined as face-to-face interactions with frequent meetings. Without these strong connections, then the radical advance in knowledge is not likely to be exploited in a timely fashion.

**Analytical Focus at the Meso Level.** The analytical focus of the ISF is the meso level of the technological sector, which others have also identified as critical (Archibugi & Pianta, 1992; Guerrieri & Tylecote, 1997; Malerba & Orsenigo, 1993, 1996; Pavitt, 1984). This meso level of arenas

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and networks is ideal for allowing one to connect to the macro institutional level of the national system of innovation and to the micro research organizations that are its constituent parts, thus also providing the often overlooked linkage between the micro and macro levels. This is important because the average scale of the research projects often varies; so too the rate of technological change and the pace of product innovation typically vary from one sector to another. For example, some sectors, such as semiconductors, see radical breakthroughs in the performance characteristics of chips every 18 months. In contrast, sectors such as pharmaceuticals have a much slower pace, despite a higher level of RTD investment. Finally, policy makers are usually interested in intervening at the technological sector level to achieve their various goals. Hence, the meso level is an advantageous starting point for development of a set of key indicators for an evaluation framework rather than the national system of innovation as the analytical focus. Further, because the meso level in this framework is connected to the macro level, it does not mean that one is ignoring this aspect of the innovation process.

**An Overview of the Scheme of Indicators.** A schematic of the general argument in the framework of indicators is in Figure 1.2. At each level—the micro, the meso, and the macro—we have chosen three sets of indicators. The three sets of indicators at each level permit better appreciation of how policies affect particular arenas of the idea innovation network as well as their connections and thus can lead to more fine tuning of these policies. With this information, policy makers can assess what they have accomplished so far and then decide where they want to be in the next five to ten years. Best of all, evaluations with these sets of indicators at each analytical level are more likely to aid identification of the obstacles or bottlenecks (Arnold, 2004). Indeed, intervention may be essential if the mission goals of the policy makers are to be achieved; thus this aspect of the framework—clearly identifying organizational, network, and institutional failures—is critical. With this perspective, the evaluator can shift from simply measuring "what is done" or accomplished to identifying "what could be."

## The Micro Level of Indicators: Balanced Investments in Arenas, Portfolios, and Organizational Profiles

At the micro level, evaluators need to be concerned about three key sets of indicators in order to assess and develop good policy guidelines for interventions. These three sets of indicators focus on aspects of the first and most common form of government intervention, allocation of research funds. Usually when governments decide to achieve a mission such as national security or become more competitive, they begin by increasing RTD spending. Before governments allocate more money, there should be an assessment of how the money (both public and private) is presently being spent and whether or not there are research gaps.

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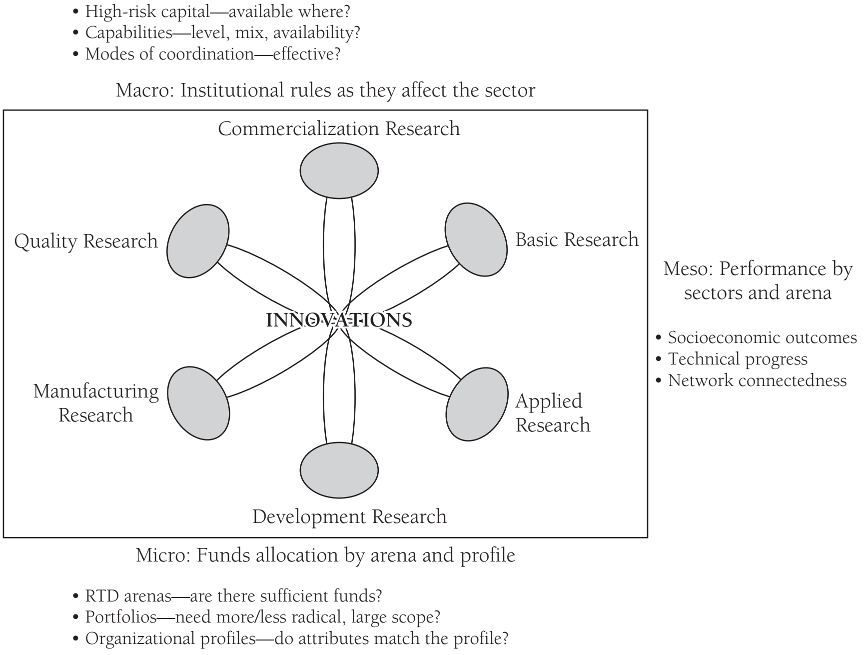
**Figure 1.2. The Innovation Systems Framework for RTD Evaluations**




The idea innovation network immediately focuses attention on the amount of investment in *each* of the six arenas and helps locate potential gaps blocking achievement of the desired throughput. Recognizing the complexity of the innovation processes also alters how one regards disbursement of RTD funds to portfolio choices, classified by the degree of radicalness and the scope of focus. Every strategic choice of incremental versus radical and narrow scope versus broad scope must be evaluated in each of the six arenas. By the same logic, this should result in reconsideration of how funds are allocated to projects and research organizations to have the desired fit between strategy and organization profile (Jordan, 2006). Furthermore, one can begin to assess whether organizational blockages are part of the reason for lack of technical progress in the strategic choices that the government has made.

**Balanced Investments Across Six Arenas.** We must begin with the objectives of government policy makers, with the critical issues being the desired aims (innovation) and identification of the most appropriate technological sector(s) to pursue these innovations. For example, the EU has recently decided to emphasize the technological sectors of health, pharmaceuticals, energy, environment, security, electronic equipment, and transport and logistics. Given the choice of these sectors for stimulating innovation, the policy maker or evaluator needs to determine the amount

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of RTD spending in each of the six arenas, including both public and private expenditures, in a sector. One issue for the assessment to determine is whether one or two of these arenas are being ignored or underfunded. Many U.S. products have lacked the quality necessary to compete in a global market, which suggests a lack of funding at least by the private sector in this arena.

Some might question the necessity of funding RTD in all six arenas. The importance of research in all six arenas is highlighted in what are typically referred to as the high-tech sectors in the United States. In these sectors, radical product innovations usually require radical advances in knowledge in more than one arena. Consider the case of semiconductors and Moore's law, which not only reflects radical advances in performance characteristics of the product but also necessitates radical advances in knowledge about how to manufacture the new generation of chips and how to achieve quality control. It could be the science may already be in place, but there is a need for some radical advances in one or two other arenas.

One of the advantages of this systemic framework for describing the complex processes of innovation is that it broadens our concept about the types of innovation beyond the usual distinctions. Product and process (manufacturing) innovation have been joined to research about commercialization and quality control, including development of new qualities. More important, the two forms of scientific research, basic and applied, are united with industrial innovation, a connection that has been underemphasized (Jordan, 2006). The key point is that a radical new product might develop out of any one or two of these arenas. Thus the word *balance* means assessing what is the appropriate amount for each arena. Although ideas move back and forth in the idea innovation network, the research problems in the several arenas, which in turn necessitate increases in expenditure, occur across time.

Usually within a technological sector, the expensive unsolved problems for research are quite well understood and can be isolated in a specific arena. In pharmaceutical research, for example, clinical trials are expensive and yet are fundamental for successful commercialization of a new drug. In automobiles it is more likely to be engineering research for product development, whereas in aircraft research the need for applied research on fuel-efficient engines and lightweight materials for the body of the aircraft are perennial research questions. Because this framework has not been used extensively and there is a tendency to focus primarily on basic, applied, and product development research, norms about the ideal amounts do not currently exist.

**Distribution of Projects by Portfolio Within the Six Arenas.** Governments choose missions, and the question is not just how much to spend but whether these missions require radical solutions or solutions that necessitate a broad scope focus. To take a European example, when France decided to develop high-speed trains it had to redesign everything, including

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ticket sales. This means radical advances in basic research, applied research, product development, manufacturing, quality control, and commercialization of research. Reporting the distribution of RTD expenditures must start with the basic question of the aims of that funding; that is, how radical an advance does the government desire in the specific technological sector being assessed? This leads naturally into another way of describing research gaps: by the distribution of spending in the portfolio.

What are some standard ways for describing portfolios? The two basic strategic choices are relative emphasis on incremental versus radical breakthrough or high-risk research, and relative emphasis on many projects with narrow scope versus a few broad-scoped programs (Jordan, 2006). Practically, we are suggesting that the amount of money, both public and private, spent in these four categories should be assessed within each arena. For example, the U.S. government would like to have radically new technologies to reduce dependence on oil. Given this, one examines the portfolio of projects in the various energy sectors associated with alternative energies and determines the relative emphasis on radical advances and broad-scope projects designed to reduce dependence on oil.

Given a decision to develop a radical product or service, the problem is then to determine which arenas should have the radical advances in knowledge. This can vary with the situation. To continue with the example of developing alternative energies to reduce dependence on oil, the choice of arena depends on the specific alternative. The science and technology for biofuels for automobiles has largely been developed. Here the problem in the United States is one of commercialization research, to determine how best to secure customer interest, and creation of new distribution systems for this kind of fuel.

Likewise, certain missions necessitate a broad scope of focus for the research. The decision about the scope of the research project is more likely to be determined by the nature of the research work in one or more arenas. In the area of alternative energies, the best example is fusion power research. Inherent in the problem is the need for very expensive equipment, a relatively large number of researchers, and expanded budgets. Here is an example of a broad scope of focus project that involves the goal of radical advances in a number of arenas, among them manufacturing (reduce the cost of cooling), quality (reducing the risk of explosion), and commercialization (how to win acceptance of nuclear energy).

In this manner, an assessment would report the distribution of RTD funds, both public and private, in each of the six arenas in four possible kinds of research projects in a portfolio:

1. Narrow scope of focus and incremental advances
2. Narrow scope of focus and radical advances
3. Broad scope of focus and incremental advances
4. Broad scope of focus and radical advances

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**Figure 1.3. Dimensions of Strategy and Structure Define Four Research Profiles**

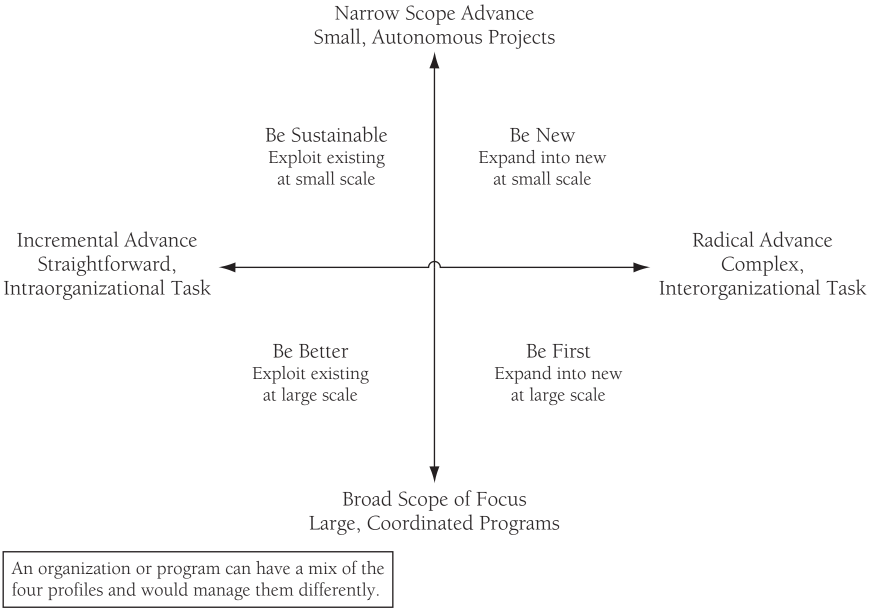


Figure 1.3 describes the four kinds of research projects. It is entirely possible that an arena would have a mixture of them, depending on the nature of the problem and the objectives of the government.

**The Distribution of Projects by Organizational Profile Attributes.** The third set of indicators for evaluation at the micro level represents an inventory of the number of research organizations and projects within each arena of the technological sector that have appropriate characteristics for achieving the research objectives in a chosen portfolio. Rather than just report the number of research organizations, which is the typical approach, our framework focuses attention on the number of research projects and organizations with particular attributes and characteristics. These characteristics are listed in Table 1.1 (see Jordan, 2005; and Jordan, Streit, & Binkley, 2003). As one can observe, there are familiar themes of the organic organization, complexity or diversity in division of labor, leaders with vision, and of course resources. The characteristics reflect organizations handling of tensions between flexibility and coordination and between inter-organizational collaborations and organizational control, to name two.

Assessment of the research environments would then report how many projects have the characteristics associated with the attributes related to radical advances in knowledge and how many have the characteristics associated with broad scope of focus, and of course both. In each instance, the

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**Table 1.1. Organizational Profile Attributes Associated with Strategic Choices**

| *Process Attributes for Radicalness* | *Process Attributes for Large Scope* |
|---|---|
| Encourage exploration, risk taking | Clearly define goals and strategies |
| • Time to think and explore | • Research vision and strategies |
| • Pursuit of new ideas | • Sufficient, stable funding |
| • Autonomy in decision making | • Investing in future capabilities |
| Integrate ideas, internally and externally | Plan and execute well |
| • Internal cross-fertilization of ideas | • Project planning and execution |
| • External collaborations and interactions | • Project-level measures of success |
| • Integrate ideas and R&D portfolios | • Labwide measures of success |
| Encourage change and critical thinking | Build strategic relationships |
| • Sense of challenge and enthusiasm | • Relationship with sponsors |
| • Commitment to critical thinking | • Champion foundational research |
| • Identify new projects and opportunities | • Reputation for excellence |

issue is to match funding for the organizational profile to chosen strategies. Table 1.1 focuses on what might be called organizational failures, which Arnold (2004) called *institutional* failures but which we believe should be kept quite separate from other kinds of institutional failures (those that are a consequence of institutional rules; Hage 2006; Hage & Meeus, 2006; North, 1990).

## Meso-Level Indicators: Six Arena Outputs, Network Connectedness, Overall Sector Performance

Increasing expenditures that are then allocated across the idea innovation network in accordance with strategic decisions made about the portfolio and awarding funds to research organizations capable of performing these strategic choices are not the only kind of policy intervention. More important is to know if the government is achieving what it desires. For example, suppose that the government has decided it wants radical innovations in a newly created set of biotech companies, as did Germany (Casper, 2006). The issue is whether these companies are in fact achieving radical biotech innovations. To have leading indicators for sector performance, one needs to assess the technical outputs *in real time* of each arena and the strength of the network connectedness within and between arenas, and then relate them to the overall performance of the sector.

**Real-Time Technical Achievements in Each Arena.** In the Hage and Hollingsworth network theory (2000), each arena is perceived to have an output. In turn, these outputs can be evaluated on the basis of how radical the advance is in that specific arena. The radical nature of the advance in the technical output is a question of the context and how a radical advance is

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defined. Radical advances reflect a large increase in the specific indicator defining the achievement in an output. Automation that improved the throughput of dishwashing machines by 300% clearly represented a radical advance as a consequence of manufacturing research. New paradigms or theories, though rare, are usually considered radical advances in science and are later recognized as such (as with Nobel Prizes). Where does peer review fit into this measurement framework? Peer reviewers usually have the knowledge necessary to define the typical rate of advance in an area as well as what is considered incremental and what would be a radical advance.

Some suggestions as to the kinds of measures of technical progress in output for each arena are presented in Table 1.2. The outputs have to be measured in real time—usually at least annually, for a number of reasons. A major one is to give quick feedback to policy makers. Papers and patents appear two to five years after completion of a project in many cases; citations unfold even more slowly. A second reason is that for policy or management intervention to be effective, it must occur while the project is still in progress. Although the reasons for lack of technical progress can adhere in many places in the innovation system, a good place to begin is with the management of the research project and whether the attributes appropriate for the specific strategic choices listed in Table 1.1 are present and to what degree.

A third reason to measure technical progress in each arena is to establish the links between short-term and medium- and long-term evaluations. This speaks to two problems: (1) the tenuousness of system evaluations of the medium and long run and (2) selection of quantifiable indicators that are easy to collect but deny the complexity of the innovation process and run the risk of irrelevancy. We believe Table 1.2 helps solve this problem. Beyond this, by establishing the missing link between short-term and medium- or long-term evaluations at the systemic level, one is also constructing a theory of the national system of innovation and developing a number of insights about institutional theory.

Measuring the technical achievements in the six outputs may appear to be an expensive and formidable task. Because each output tends to be the concern of a particular agency or ministry, the cost can be spread among them; the information about each arena individually is of value and collectively more than the simple sum of the six parts. For example, the ministry of the environment would want to know if the products are being manufactured with qualities that protect the environment in various ways; the ministry of commerce is interested in establishing new methods for advertising and distributing products; and the ministry of technology, if there is one separate from a ministry of science or industry, is more concerned with research on manufacturing and product development.

Further, Table 1.2 offers suggestions for each arena, but it may not be necessary to measure all six. This is a question of how much functional differentiation has occurred. For example, if basic, applied, and product development

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**Table 1.2. Indicators of Technical Output for Each Functional Arena in the Idea Innovation Network**

| *Functional Arena* | *Measures of Scientific/Technical Advanced in Output* |
|---|---|
| Basic research | • Percentage increase in modeling of some scientific behavior<br>• Solution to a central problem<br>• Identification of new concepts or processes |
| Applied research | • Percentage increase in control over some desired attribute |
| Product development or product innovation | • Percentage increase in performance characteristics weighted by their importance<br>• Addition of new properties to the functionality of the product |
| Production research or process innovation | • Percentage increase in productivity<br>• Percentage increase in customization |
| Quality control research and research on qualities | • Percentage decrease in defects<br>• Percentage decrease in operating costs<br>• Percentage decrease in various externalities weighted by their importance |
| Commercialization research | • Percentage increase in customer satisfaction<br>• Percentage decrease in delivery time |

research are combined in a biotech company, and if the manufacturing, quality, and marketing research are combined in a pharmaceutical firm, one can concentrate on the technical outputs of product development of the biotech companies and the product outputs of the pharmaceutical firms. This represents only a first approximation; again, it may be necessary to examine the outputs of the other arenas within the biotech companies and the pharmaceutical firms because blockage can be organizational, with bottlenecks between basic and applied research in the biotech companies or between manufacturing research and quality research in the pharmaceutical companies. For this, internal network analysis can be quite valuable (Mote, 2005).

As more and more of the arenas become functionally differentiated, one is forced to measure the technical outputs of each arena. It speaks to the issue of understanding the innovation processes at the level of the idea innovation network in a technical sector, avoiding the errors in the business systems literature and other institutional studies that tend to generalize from one technological sector to all others (Hollingsworth, 1997; Whitley, 1992a, 1992b).

**The Strength of Connectedness Between Arenas.** It should be clear that the six arenas of the idea innovation network need to have strong connections to have the desired result. In the past, when all arenas were within

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the same organization as with Siemens, DuPont, and Procter & Gamble, the issue of connectedness did not present a significant problem. However, over time connectedness has become problematic, even within the same organization. For example, disconnectedness occurred between Bell Laboratories and AT&T and between the research department (PARC) of Xerox and the main company. The real problem starts to grow as an entire functional arena becomes disconnected; an example is all of basic research being located outside the other organizations involved in some technological sector. The van Waarden and Oosterwijk (2001) EU study indicates how these evolutionary processes have unfolded in telecommunications and pharmaceuticals in Austria, Finland, Germany, and the Netherlands. A number of new subnetworks in specific arenas emerged to handle the problems of technical advances, and in turn they were connected to the larger sector network of knowledge transfers.

As each arena becomes differentiated into separate research organizations, concern grows as to the extent of the connection between these differentiated arenas. Even more important is the strength of the connection. Hage and Hollingsworth (2000) argue that as the radical nature of the technical achievement in a specific arena increases, the more frequent and intense must be the interaction with other arenas to transfer the tacit knowledge involved in the radical advance.

What reveals the strength of the connection? Here are some indicators: (1) transfer of people from one research group to another, both within and among organizations; (2) joint research projects involving face-to-face collaboration among researchers, as distinct from long-distance collaboration; (3) joint publications; (4) the strength of managerial, financial, and research ties among organizations in joint ventures; and (5) the strength of ties among actors in research consortia (Nieminen & Kaukonen, 1999). Van Waarden and Oosterwijk (2001) observe a large number of ways in which connectedness was established: joint ventures, user groups, product teams, patent pools, collective trademarks, technology clusters, partnerships, alliances, and even virtual firms. But it should be observed that having a number of these mechanisms present does not necessarily reflect transfer of tacit knowledge. Just as one wants to measure the knowledge advances in each arena, one also needs to measure exchanges of tacit knowledge within and between arenas, especially the differentiated ones.

The idea innovation network highlights two kinds of networks that should be of concern for policy makers, and thus evaluators, to measure: subnetworks of small research organizations within an arena, and networks of organizations (whether small or large) across differentiated arenas. The former are important when governments are interested in creating technical pools, which was clearly the objective of the U.S. government when it changed its antitrust laws to encourage research consortia. In this instance, some of the research consortia involved quite large organizations, primarily

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concentrated in the basic and applied arenas of research, leaving product development to individual companies that desired to pursue particular market niches. In contrast, the networks of organizations become especially important in linking differentiated arenas. But that said, the more critical point is that it is not necessary and may even be counterproductive to have networks and subnetworks everywhere.

Recently a large number of network studies have emerged, including the new research on visualization tools that mine large data sets involving papers, patents, and citations of either papers or patents or both (Börner, Sanyal, & Vespignani, 2006; Wagner, 2005). Many of these efforts are attempts to measure the payoff from investments in RTD. However useful these network analyses are for examining the consequences of certain government policies, they are focusing on what *is* rather than what *can be*. The ISF and measurement of connectedness in real time attempts to inform government about network failures or "what could be." With policy reformulation, government could potentially achieve more payoff from its investments in science than it does presently.

**Overall Performance of the Technology Sector.** The technical outputs of each arena are a means to an end, locating one of the reasons a nation may not be achieving its goals. The lack of connectedness can be another reason. But in the final analysis, evaluators need to assess the overall performance of the technological sector. Rather than a single assessment of the overall performance, we suggest these dimensions:

- The degree of radicalness on the various dimensions of the product mix
- The average speed of product dimension development or time to market
- The commercial success of the product mix in sales and trade balances or the technological position globally

It goes without saying that the level of analysis here is not the single research organization but all of those concerned with producing products in a particular technological sector and therefore the product mix in the technological sector. First, although we are using economic examples, we argue that the same logic can be applied to health products, military weapons, and national security. The industrial innovation literature (Hage, 1999; Hage & Meeus, 2006) has tended to focus on product innovation and even radical product innovation in terms of functionality rather than observing that it is one of a set of interrelated dimensions. Second, consistent with the repeated importance of research on qualities, and research on customization of manufacturing, product mixes at the sector level should be evaluated along a variety of dimensions to understand correctly the competitive position of the country. Third, it is fairly easy to determine the competitive position of the product mix for policy makers using trade journals and statements of marketing executives who

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are acutely aware of the relative strengths and weaknesses of their products in a global context.

Also, the average speed of development across the various dimensions involved in the product mix has increased and become a critical factor in maintaining a country's competitive position in the high-tech sectors. The Japanese set the bar quite high when they created the hybrid car, a radical product innovation, in just 15 months (Nonaka & Peltokorpi, 2006).

## Conclusions

Recent calls for theory-led evaluation and better analyses of the systemic obstacles and blockages to innovation to explain why policy objectives have or have not been reached reflect a new era in RTD evaluation. These changes in the methodology of evaluation focus on what could be rather than what is done. If theory-led evaluations can determine what obstacles or blockages are preventing realization of the objectives of policy makers, then governments could begin the process of designing better interventions to achieve more effective innovation.

But which theory or theories should lead the evaluations? Although some have called for use of national systems of innovation literature, this literature is largely descriptive and covers only the macro level. We have suggested that the systemic framework should be a theory-led evaluation, that is, include theories from the macro, meso, and micro levels. One advantage of starting to construct the innovation systems framework with the idea innovation network theory of Hage and Hollingsworth (2000) is that is helps integrate these other literatures at the same time that it affords a more complex perspective on the throughput of the innovation processes. Theories from each of the three levels are essential if one is to understand the blockages and obstacles because they could be located in any part of the system.

Despite pleas from governments that one analyze the entire scientific and technological system, we suggest that instead it is more desirable to evaluate sector by sector. If need be, these separate sector analyses could be combined into a total assessment. Another implication of the call for analysis of blockages and obstacles is that technical advances have to be measured in real time rather than waiting for the appearance of papers, patents, and citations to them. If governments are ever to focus on improving policies, they must have quick feedback, not only on whether they are failing to achieve their objectives but more critically on the reasons. Only then can governments learn how to fashion policies to improve. Only then can evaluators relate short-term accomplishments to long-term sector performances. Then evaluations would truly inform governments and reduce the current cynicism about evaluation that almost always states that research investments are successful.

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The ISF for RTD evaluation can inform not only governments but the theories that have been used to further construct the framework. The efficacy of various theories can be tested across the three levels of analysis (macro, meso, and micro contributions to any particular issue). Government interventions, if evaluated this way, could then supply some important answers to questions that have been imposed in these various literatures: What are the best kinds of linkage for the transfer of tacit knowledge? Can governments overcome path dependency? How much autonomy do research organizations have from their institutional environment? Answers to questions such as these would considerably advance the sophistication of social science theory.

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