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A theory-based innovation systems framework for evaluating diverse portfolios of research, part two: macro indicators and policy interventions

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This framework for multi-level evaluation of scientific research is a bridge between social science theory and the provision of effective feedbacks to governments so they can overcome systemic blockages to innovation and successful outcomes of research policy. Starting with the idea of innovation network theory and organizational theory involved in the research environment survey, a small set of indicators is suggested at micro, meso, and macro levels. Data from this integrated set of indicators can identify the blockages and suggest corrections. This paper concentrates on the macro-level indicators. Three familiar kinds of government policy lever — capital, capabilities, and coordination modes — are discussed. However, the discussion of ways in which these interventions can correct blockages is far more complex than has previously been acknowledged in the evaluation literature. The proposed framework is an important step for evaluators and policy-makers to develop research, technology and development investment portfolios and strategies more effectively.

IN RECENT YEARS, there has been a growing demand for multi-level, systems-based frameworks for evaluating research and innovation policy (Arnold, 2004; Molas-Gallart, 2006). In response, we have developed a theory-based framework that relies on a set of indicators at each of three levels: the micro level of the research organization; the sector or meso level of the idea innovation network (Hage and Hollingsworth, 2000); and the macro level of government policy.

As we discuss in this paper, our framework offers a solid foundation for the integration of social science theories and offers a more comprehensive view than has been available to date of how the innovation system works to allow for more targeted evaluation studies. In addition, the framework attempts to identify blockages and obstacles, or what Arnold (2004) labels “failures”, that can then inform policy interventions to improve the quality and timely impact of scientific research.

As indicated in the title, this is the second of two papers. The first paper (Jordan *et al*, forthcoming) concentrates on the micro- and meso-level indicators of our framework and describes the process of research funding, strategy and connectedness within the context of the idea innovation network. In contrast, this paper primarily focuses on macro-level indicators of our framework.

The adoption of a multi-level framework recognizes that government policies should be more finely tuned than is typically prescribed by the national

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innovation systems literature, especially if policy-makers are oriented towards specific societal outcomes. In the framework, we argue for focusing on specific technological regimes because scientific disciplines and technological outcomes and products differ greatly across sectors, as do the attendant outcomes (Guerrieri and Tylecote, 1998; Malerba and Orsenigo, 1997).

In developing the framework, we have sought to strengthen the theory of the national innovation system (Nelson, 1993) in two important ways. First, we synthesize three distinct literatures at the micro level, specifically those on the management of innovation (Brown and Eisenhardt, 1995; Judge *et al*, 1997; Leifer *et al*, 2000; Verhaeghe and Kfir, 2002), the organizational sociology of innovation (Hage, 1999; Hollingsworth, 2000), and the profiles theory of innovation (Jordan, 2005; Jordan *et al*, 2005; Jordan *et al*, 2003). Second, we synthesize new theories about the idea innovation network (Hage and Hollingsworth, 2000) and, more broadly, knowledge communities (Mohrman *et al*, 2006).

In this paper, we discuss our framework, with emphasis on the macro level, within the context of three common policy questions:

- Where to invest?
- What capabilities are needed and where?
- Which coordination mechanism should be used and where?

Each question is addressed in a separate section and, as one would assume, the questions are highly interrelated. First, we begin with a brief overview of our innovation systems framework and the theories that we have integrated into the national systems of innovation literature. Our discussion of the three policy questions is largely derived from the macro-level implications of integrating these theories into a coherent, systemic framework. Next, we discuss each of the three policy questions within the context of our framework. Finally, we conclude with a discussion about implications of the framework for government policy regarding science and innovation.

Overview of innovation systems framework

Building on the work of Kline and Rosenberg (1986), the foundation of the innovation systems framework is the idea innovation network (Hage and Hollingsworth, 2000), which delineates six primary arenas in which research findings are produced: basic research; applied research; product development; manufacturing research; quality research; and commercialization research. These arenas are all present in every technological sector, and we would argue that the technological sector is the most sensible target of analysis because of the differences across technologies.

Hage (1980) and Pavitt (1984) have shown that the kinds of outcomes or innovations are different in these sectors, thus requiring different measures for evaluation. Furthermore, as the idea innovation network becomes more differentiated, the evaluation becomes more complex. The interconnected arenas are conceptualized as an idea innovation network because the assumption is that innovations in any of the six arenas can lead to innovations in any one of the others, although not necessarily in a linear fashion.

More critically, we argue that consistent, sustained research progress is needed in all six arenas to reach desired outcomes and thus to have an effective research, technology and development (RTD) research policy. The idea innovation network is fundamentally dynamic, with innovation driving greater differentiation of knowledge. As Hage and Hollingsworth (2000) observed, the introduction and expansion of new knowledge (through innovation) has a spillover effect of differentiation by creating new disciplines, occupational capabilities, technological capabilities and research organizations. For example, Figure 1 illustrates how the new paradigm of molecular biology, a new occupational specialty, coupled with new research techniques involving the splicing of DNA, lead to the differentiation of new bio-tech firms focusing on applied research and product development in the industrial sector of pharmaceuticals.

The meso level of the idea innovation network plays a critical role in our framework, as it provides

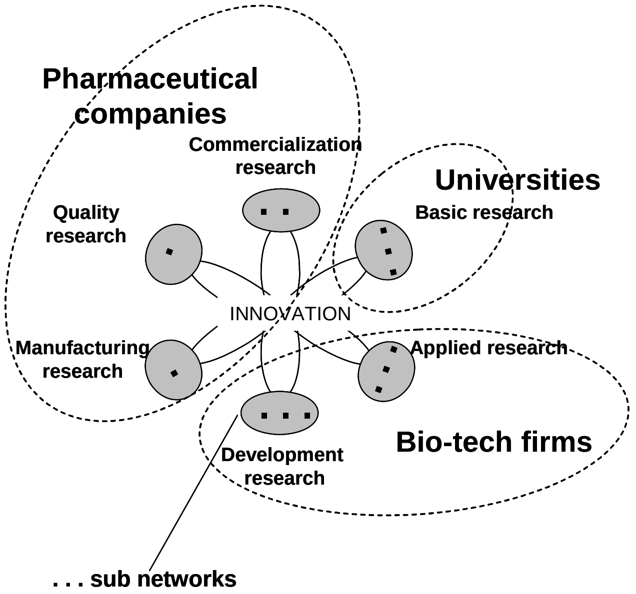


Figure 1. The Idea Innovation Network Theory: example of microbiology

The use of three levels responds to the call for a knowledge production theory with these three analytical levels and gives the opportunity to contribute to other theories and frameworks, such as organizational learning, knowledge communities, and econometric input–output evaluation models

clearer focus and direction for policy-makers at the macro level. The meso level also connects to the micro level by means of Jordan's (2006) theory of research profiles and previous work on industrial innovation (Hage, 1999), which focuses on the level of research organization and is primarily concerned with identifying potential organizational obstacles to innovation (see Part I (Jordan *et al*, forthcoming)).

Together, the use of three levels responds to the call for a theory of knowledge production that contains these three analytical levels (Meeus and Hage, 2006) and provides the opportunity for contributing to other theories and frameworks, such as organizational learning, knowledge communities, and standard econometric input–output evaluation models. Within each analytical level, we identify three sets of indicators that provide guidance for policy-makers, and indicate specific possible blockages and obstacles (see Figure 2).

In general, the micro-level indicators focus on how to allocate funds using the criteria 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. In contrast, the meso-level indicators measure the outputs of each arena in real time, the strength of the connectedness among differentiated arenas, and the overall assessment of innovation performance, including societal impact.

Where to invest?

At the macro level, governments have traditionally approached RTD investment decisions as a set of three choices: between disciplines, such as nanotechnology or bio-technology; between research technologies, such as the International Linear Collider (ILC) or the Large Hadron Collider (LHC); or between research applications, such as hydrogen cars, health care, or high-speed trains. Guiding these decisions have been important considerations about the socio-economic benefits of such investments, both immediate and in the future. In terms of

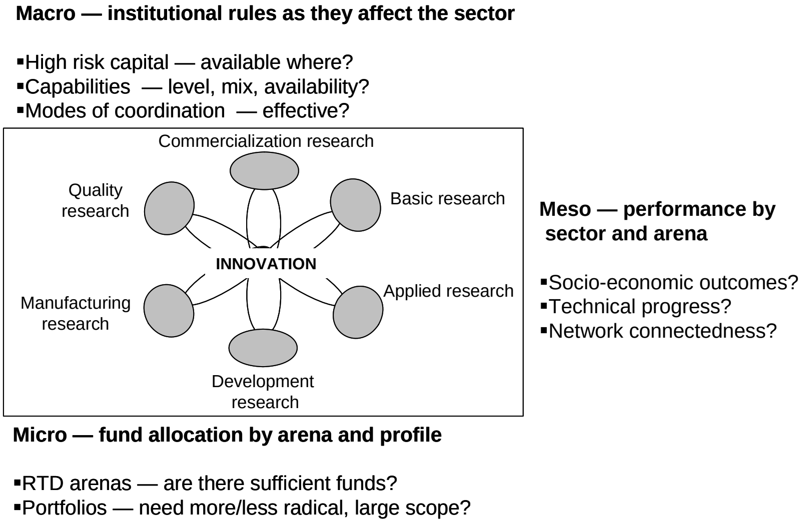


Figure 2. The Innovation Systems Framework for RTD evaluation: a small set of key indicators

investment efficacy, however, it is necessary to consider the complexity of systems of innovation.

Another way of stating the same question is: where do gaps exist in RTD funding where a little increase in investment can achieve a noticeable impact on a desired outcome? We would argue that the answer to this question should be driven in part by considerations that reside at the micro and meso levels, that is, at the levels of research organizations and the idea innovation network. As Figure 3 indicates, these two levels introduce a range of selection criteria for policy-makers at the macro level to consider for making appropriate investments.

To begin to answer our reformulated question about where to invest, it is necessary to have a cognitive map of the knowledge-production system, starting with the meso-level of the idea innovation network theory. In general, the six arenas, which reflect six different avenues for RTD investment, provide the first selection criteria for investment in a particular science or technology sector. Moving beyond a simple basic/applied dichotomy, a significant advantage is that the framework can help diagnose an important reason why policy objectives are not being met, namely ignored or under funded research arenas.[1]

For example, let us assume that policy-makers have conducted an evaluation of the effectiveness of a specific technological sector and found that part of the problem is under-funding, both public and private investment, in a particular arena. Faced with this knowledge, it is necessary for policy-makers to determine the amount that *should* be invested in each of the arenas of the idea innovation network in that sector.

However, to allocate scarce public resources more efficiently, it is essential for policy-makers to know the amount of private investment that is already in the system. For instance, it is widely noted that there has been a long-term trend for industry to move out of basic research (Shackelford, 2007). Private investment is driven by profit and may ignore particular arenas, such as manufacturing research (paradoxically) and quality research, particularly in terms of the reduction of negative externalities.

Further, policy-makers have a responsibility to take the larger collective view, especially when it comes to reducing externalities within and even across sectors, such as research on environmental impacts or research to accelerate the introduction of renewable-energy technologies. As this hypothetical example illustrates, our framework allows for a more comprehensive perspective on the innovation system, and the ability to drill down to a greater level of specificity.

Strategic choices/profiles of research in each arena

At the micro level, the knowledge-production system consists of a range of research organizations that produce various kinds of research results. At this level, the set of second selection criterion requires an appreciation of the kinds of strategic choice that policy-makers and scientists should make when designing research projects (Jordan, 2006). In Figure 4, we highlight the four types of research profile associated with two primary strategic choices: the relative degree of risk or desired discontinuity; and the relative scope of the research problem or its systemic character.[2] As we discuss below, these four types represent another set of selection criteria based on the research strategy one wants to pursue.

For scientific research, the task environment is the knowledge world, particularly in relation to ‘the state of the art’, that is, how much is known and what is considered an important scientific concern or requirement. With this in mind, the first strategic choice reflects how much of an advance or discontinuity will be pursued in relation to the current state of the art. This strategic choice coincides with the distinction

Which arena(s) in the idea innovation network?

1. basic research
2. applied research
3. product development or proto-type research
4. manufacturing research for speed and efficiency
5. quality research to improve quality and to reduce externalities
6. commercialization research (probe and learn)

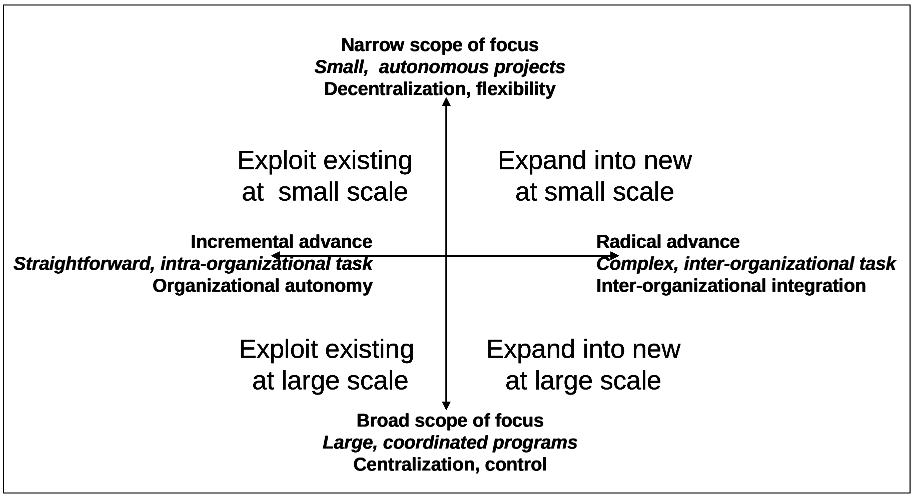
Which strategic choices or profiles of research within each arena?

1. small scale or scope normal science
2. large scale or scope normal science
3. small scale or scope high risk major breakthroughs
4. large scale or scope high risk major breakthroughs

Which organizational profiles within an arena?

1. projects with cross-functional teams defined as in the idea innovation network
2. projects with high cross-fertilization of technical and critical ideas
3. projects with high numbers of collaborations, internal and external
4. projects within complex departments as measured by specialization
5. projects with autonomy of technical decisions
6. projects with a diversity of inter-organizational relationships

Figure 3. Micro-level selection criteria for RTD investments within a particular sector



An organization or program can have
a mix of the four profiles and would manage them differently.

Figure 4. Research profiles theory: dimensions and categories

typically made between incremental and radical innovation (Garcia and Calantone, 2002; McDermott and O'Connor, 2002). The more that one desires a significant advance, the higher the risk or the uncertainty of achieving this objective (Raz *et al*, 2002; Roussel *et al*, 1991). Hence, this strategic choice reflects a dilemma for governments between supporting normal science, which is primarily incremental advances, or high-risk breakthroughs or, perhaps more appropriately, some balance along a continuum.

Another dilemma is posed by the second strategic choice, that is, the definition of the scope of the research. Many sciences are inherently systemic, such as the earth or atmospheric sciences, where studying a component, or part, of the problem is not easily accomplished in isolation. However, a great deal of science does proceed in a non-systemic manner, studying particular components and problems in isolation. Over time, more and more scientific problems are perceived to be complicated, both because of external factors that must be taken into account and internal processes that must be modeled more or less well to improve the quality of the prediction (Boesman, 1997; Miller and Morris, 1999). These same distinctions are meaningful in the context of industrial research for new products. For example, there are product subsystems on the one hand, such as cars and airplanes, and, on the other hand, research for developing components such as chips, which are then used in other systems.

With regard to the second selection criterion, the primary policy decisions revolve around adopting the appropriate mix of research according to the profiles. While a balanced approach may be optimal, a challenge facing policy-makers, given ongoing interest in radical innovation, is the amount of investment in high-risk projects, either small or large scope. At this level, a significant challenge lies in the classification of projects and profiles and monitoring their progress. In general, typical measures of research performance, such as patents, papers and citations, are lagging indicators and do not adequately address the progress of the research (Mote *et al*, forthcoming).

However, it is not sufficient to know that research is relevant, that the ‘right research’ is being conducted, or that past research was successful. As Feller (2002: 444) states with regard to federally-funded research, “perhaps the most telling limitation of performance measurement as applied to science policy is that whatever its value may be in tracking past performance, it is of limited value for prospective decisions.” The only solution to this problem is to develop meaningful measures of progress and the discontinuity of that progress that can be applied on an annual basis, and then to invest in those projects that have achieved progress and are relevant to desired outcomes.

Organizational characteristics in specific profiles

When we move to the third selection choice, we suggest another reformulation of the way that policy-makers should consider resource allocation. Once a programmatic area has been selected for investment, projects are typically chosen according to merit, usually on a competitive or peer-reviewed basis. While we do not suggest supplanting this, we would propose that policy-makers also select projects that are structured in a way that is likely to increase the possibility of achieving the type of research pursued, particularly research geared towards discontinuous and radical advances.

To do this, we again draw on the research profiles theory (Jordan, 2006; 2005), which identifies and categorizes a series of important attributes for conducting excellent research in each of the profiles. The scope of the project or program, or the number of components or problems being studied, is mirrored in the project’s size as measured by investments of equipment, researchers, and money. From the size of a project flow a number of consequences that create tensions about coordination and control mechanisms that inevitably impact on

What kinds of technologies and skills within arenas?

1. new tools, new technologies, new methods, and new models
2. new research programs
3. new training facilities or occupational specialties

What kinds of research organizations or firms should be differentiated within arenas?

1. new research platforms for conducting experiments
2. new research organizations
3. new high tech companies (small or large)

What kinds of linkages within and between arena(s)?

1. training of inter-disciplinary individuals and boundary spanners
2. joint ventures, inter-organizational networks, global alliances
3. science-industry parks, Silicon Valleys, geographical regions

Figure 5. Selection criteria for building capabilities within a sector

research autonomy (Jordan, 2006). Further, the scope also reflects the complexity of research, as represented by the variety of scientific and engineering disciplines involved (Hage, 1980; Hagstrom, 1965; Kim and Wilemon, 2003; Shenhar, 2001).

With these considerations in mind, the funding decision is not only about investing in particular kinds of research project on the basis of the strategic choices, but also selecting projects on the basis of management and structural characteristics. With regard to the selection criteria, we have focused on six categories of attribute that have been identified in the literature as most amenable to high-risk, radical research: cross-functional teams; cross-fertilization; internal and external collaboration; complexity; autonomy; and inter-organizational diversity. In addition, we have included the network connectedness as another key metric at the meso level of our framework (Jordan *et al*, forthcoming). In addition to the identification of these attributes, Jordan (2005) has developed and extensively tested a survey instrument that measures these attributes based on the perceptions of workers: this could be utilized by policy-makers for investment decisions.

The importance of these attributes for research is well-grounded in the literature. For example, the themes of cross-functional teams, cross-fertilization of ideas, and collaborations of various kinds have received substantial emphasis in the management of innovation literature (Balachandra and Friar, 1997; Brown and Eisenhardt, 1995). Hence, it is incumbent on policy-makers at the macro level to consider these issues in making investment decisions.

Which capabilities and where?

As our discussion of the micro and macro levels of our framework and investment illustrates, taking a multi-level view introduces a number of finely grained investment criteria for policy-makers. The same is true for the building of capabilities, which could be roughly defined as the knowledge creation and distribution capability of an innovation system (David and Foray, 1995). Direct investment in research is only the starting point; there must be a strong and robust infrastructure to support researchers and the distribution of knowledge.

As Figure 5 illustrates, we identify three primary types of capability: human capital and technological instruments; new organizations; and integrative mechanisms. Of these, the most important may be the education and training of individuals so that they can be integrative across functions, whether in teams or broad-scope projects.

Personal skills and technological instruments

In utilizing the idea innovation network theory for an evaluation frame, the assessment of capability takes on a whole new meaning. Rather than just determining the overall number of scientists and engineers, it becomes essential to determine how many of these are being trained with the appropriate skills and conducting research in each of the six arenas. One part of the problem is the training of individuals for more specialized areas of research. Policy-makers also need to assess the capabilities of technical specialists for operating the increasingly sophisticated machinery associated with scientific research.

Another important capability is the development and construction of research tools and equipment, and the techniques and methods for operating them, for conducting research on the cutting edge. The more difficult question for policy-makers is deter-

A difficulty for policy-makers is determining the availability of scientists, engineers, and technologists in the six arenas when the portfolio has been shifted in the direction of increasing emphasis on radical innovation and/or large-scale projects

mining the availability of scientists, engineers, and technologists in the six arenas when the portfolio has been shifted in the direction of increasing emphasis on radical innovation and/or large-scale projects. Rather than being a question of a certain kind of capability, perhaps, it is more a capacity for risk-taking that is important.

A further important issue to consider is the evaluation of capabilities when the pace of radical innovation is rapid, which requires the creation of new competencies (Anderson and Tushman, 1990) or new disciplines, such as in nano-science and nano-technology, or as various sectors begin to merge together or have synergistic effects, as in the telecommunication, media, and computer arenas. To exploit the potential in these new areas, it is necessary to have individuals and teams with the requisite skills. One of the more interesting problems for policy-makers is to determine what new academic programs are needed so that scientists and technologists are sufficiently trained in particular areas.

Kinds of research organization to be differentiated

A critical implication of the idea innovation network theory is that, as knowledge grows, particular arenas have to become differentiated for continued success within a specific scientific-technological regime. In Figure 5 we listed three common kinds of new organizational capabilities that may have to be built: research platforms, research organizations and research firms.

Research platforms provide a common foundation of test-beds and tools for a wide range of researchers. For example, Malo and Geuna (2000) describe the development of combinatorial synthesis methods, which provided a fertile research platform for drug and new material discovery. In addition to fostering the development of research platforms, policy-makers can play a significant role in transferring this knowledge to the commercial arena by providing the necessary policy and regulatory infrastructure (Malinowski and Littlefield, 1999). Further, the private sector can play an important role in this regard, as exemplified by the establishment of SEMATECH and the development of common research platforms in semiconductor manufacturing (Browning *et al*, 1995).

Successful research organizations, and more critically effective idea innovation networks, are more than just a question of hardware and the human capital. Success also means the creation of new organizations. While the idea innovation network theory suggests that organizations differentiate to develop better focus, it is also the case that this process may unfold too slowly, particularly during periods of rapid innovation. In these cases, policy-makers may want to explore the creation of new organizations to exploit new, differentiated knowledge more quickly.

Most recently, the US Department of Energy (DOE), as part of the National Nanotechnology Initiative, established five user facilities to explore new knowledge in nano-scale materials. As part of this effort, the DOE is providing the specialized training, support staff and tools needed to exploit this rapidly advancing area of science (Roco, 2001).

Kinds of integration mechanism

When gaps emerge in the idea innovation network or there are problems of communication in cross-functional teams, policy-makers need to be concerned about building what we call integration capabilities. The first approach is to educate and train individuals so that they can effectively act as integrators between two or more arenas. In the organizational literature, these individuals are often referred to as boundary spanners (Aldrich, 1979), and they have been shown to be critically important actors within knowledge networks (Liebeskind *et al*, 1996; Tushman and Scanlan, 1981).

While training programs for this kind of activity may not be feasible (or useful), policy-makers could encourage organizational policies that facilitate integration across disciplines and functional arenas. For example, in the larger public-research organizations in the United States, it is common to find two leaders attached to each research project, reflecting the influence of a matrix management style (Larson and Gobeli, 1989). In this structure, the project leader focuses on the science or technology, while the project manager is largely occupied with the administrative and budget tasks.

To this project team, one could feasibly add an individual whose primary concern would be the integration of the project team, through the reduction of communication barriers within cross-functional teams, and integration within the organization or the larger knowledge community, through seeking out contacts to other functions and attempting to create networks with them for the passage of technical information. In this manner, this function plays a much needed role in building networks throughout the entire idea innovation network.

At another level, policy-makers can create organizations that act as bridges between arenas. For example, the National Science Foundation started a program to fund joint government–industry centers at universities to work together in a high-tech program of joint concern. Further, some European countries, such as the Netherlands, have used technology centers as a mechanism for attempting to coordinate among basic, applied and product-development research. One clear and proven example of success is the creation of such a coordinating center in Taiwan (Hage and Hollingsworth, 2000). More recently, the European Union has discussed the idea of national coordinators that help foster innovation (Aho *et al*, 2006).

Which coordination mechanisms and where?

In addition to investment capital and capabilities, it is necessary to consider the coordination of this complex ecology of research, researchers, organizations and knowledge. While the choice of coordination mode to be given primacy within and among arenas is critical, it is often overlooked by policy-makers. Instead, the usual practice is to continue in a path-dependent mode, relying on the dominant historical (or perceived) modes with slight changes on the margins (Niosi, 2002). All too often, a *laissez-faire*, quasi-market approach to coordination is adopted. Yet a rich array of possibilities exists, including the familiar framework of markets, hierarchies, and networks (Powell, 1990).

Part of the reason why policy-makers fail to consider other forms of coordination is that a relevant framework does not exist for selecting alternative, and perhaps more appropriate, coordination modes. The four basic choices for the coordination within arenas, across arenas and across regimes or sectors are: markets; hierarchies; the state; and the network. These can be disaggregated further into associations and inter-organizational networks to accommodate different interactions. These distinctions are important because the market mechanism is limited in its applications, particularly with regard to exchanges of technical information and, specifically, as the proportion of tacit knowledge increases (Gibbons, 1994).

The laws of supply and demand have been constructed for consumers who know what they want and producers who can anticipate them or cater to their tastes, yet this framework is not clearly applicable within a public policy context (Bozeman, 2002). In the world of science, we more frequently encounter scientists who, if they can obtain funding, do research on what interests them without practical implications, and managers are often not sure what kinds of research funding would improve competitiveness and create innovative products (Martin and Scott, 2000).

It is this mismatch between what science produces and what industry needs that has led some, such as Stokes (1997), to argue for the creation of a science policy that emphasizes the combination of basic and applied research. This is an important step, but the combination of these types of research necessitates some kind of coordination mode that allows for effective integration of the different world views and disparate interests.

Developing a theoretical framework theory for coordination modes is beyond the scope of this paper, but we can begin a discussion by indicating some relevant contingencies and how these vary depending on what is being coordinated. It should go without saying that coordination often fails and, in the case of science, it is not just market failure but also failure of hierarchies, particularly in the sense of state hierarchies. As we discuss below, these failures can be identified and measured by the existence and size of gaps in the idea innovation network.

Measuring the size and location of the gaps

Before we discuss the selection of coordination modes, it is first necessary to discuss the notion of gaps in the idea innovation network and how these can be identified and measured. As with the selection of research projects and organizations, we would suggest that the research environment survey (Jordan, 2006; 2005) would be useful for identifying and measuring the size of the gap, at least at the level of the research project, as well as determining some potential causes of the gap.

Most simply, we define a gap as the number of arenas that have no direct connection with the arena in which the project is located. The size of the gap can be a combination of a number of things, including the extent of communication, critical thought, and exchanges of technical knowledge. In our discussion of the determinants of the extent of innovativeness, we observed two other potential areas where gaps in the idea innovation network might arise: lack of diversity in cross-functional teams; and lack of diversity of functions represented in inter-organizational collaborations.

While the creation of integration mechanisms at the level of research project addresses one set of blockages that might account for gaps, these do not represent the only types of blockage that could be encountered. Another could be at the level of the research organization, particularly in terms of the organizational and management polices faced by research projects. Indeed, it is at this level that government policy-makers can have a decisive impact on the strategy of the research organization, especially if it is a public one. For example, research organizations might attempt to pursue a strategy of technology transfer, which would perhaps allow for the elimination of some gaps in the idea innovation network (Bozeman, 2000). Further, research organizations often create intra- and inter-organizational centers that facilitate the ability of research projects to pursue internal and external collaborations, again eliminating some gaps.

Contingencies for determining coordination modes

The first and most obvious contingency is the importance of exchanging tacit knowledge, which is often assumed to be critical for organizational learning (Cohen and Sproull, 1995). In the knowledge paradigm of the firm (Brown, 2000; Conner and Prahalad, 1996), the problem of how to achieve the effective exchange of tacit knowledge has been recognized, but there has been limited research on how this is best achieved (Ambrosini, 2001).

One of the easiest ways of facilitating the exchange of tacit knowledge is through the construction of cross-functional teams, as these are associated with higher communication. However, as yet, it is not clear that cross-functional teams are completely or automatically integrated enough for the passage of tacit knowledge. As Nooteboom (1999) discusses, increasing the number of functions within a team also increases the cognitive distance among team members, thus making integration with cross-functional teams imperative. Cognitive distance in cross-functional teams that span organizational boundaries further exacerbates the exchange of tacit knowledge because of differences in organizational cultures.

Regardless of these qualifications, it would appear that inter-organizational teams that combine disparate functions are the coordination mode of choice, provided that they are effectively integrated. Recently, we discussed a number of mechanisms for achieving better integration within these teams (Hage *et al*, 2007). Some of the more interesting ones were the use of dual leadership for research teams, the rotation of members through several departments, and, perhaps most critically, treating all the individuals as though they are a member of a research ‘family’.

Another contingency to consider is the speed with which research outcomes in one arena need to be passed to another or how quickly the societal objective must be achieved. Under these circumstances, the use of market mechanisms, when we consider such things as papers, patents, and conferences, are typically slow and policy-makers can ill afford to wait for the formation of the inter-organizational networks that are necessary for the transfer of tacit knowledge. This sense of crisis leads to the formation of large-scale projects like the Manhattan project, wherein a state-led hierarchy is established with the objective of coordinating the disparate research problems associated with successful completion. A more modern day example is the Human Genome Project, which significantly accelerated the sequencing of the human genome (Collins *et al*, 2003).

A common contingency that would necessitate a coordination mode other than that of the market is the need to combine different interest groups in the same decision-making process to accommodate disparate interests and facilitate communication. Since basic research is largely, and increasingly, based on public funding, and research on manufacturing and quality tends to be funded by the private sector, this is a fairly common pattern. Given this contingency, the use of associations would seem to make a great deal of sense. While the importance of such associations is typically assumed, they are often not explicitly recognized by policy-makers as a potential tool for advancing objectives. We would note that the USA’s Government/Industry Co-sponsorship of University Research (GICUR) program represents a step in this direction (McGeary and Hanna, 2004)

Applying coordination modes to gaps

First, we consider the problem of gaps within specific arenas in the idea innovation network. We suggest that this is not a principal concern for policy-makers, unless a strategy is pursued for fostering regions akin to Silicon Valley, that is, regions with a large number of firms with similar technical expertise. A particularly illustrative example of the success of combining firms within the same arena is SEMATECH, the collaborative organization focused on accelerating advances in semiconductor manufacturing. What makes the case of SEMATECH particularly interesting is that all the participants had the same basic knowledge and yet, at the same time, the combining of their technical knowledge resulted in a more effective knowledge pool. Furthermore, this is an instance in which the government changed an institutional rule, namely it deregulated and allowed firms to form associations for the purposes of research.

A more important concern for policy-makers is when gaps are located between arenas, which necessitates a more active role in creating new coordination modes. The circumstantial evidence appears to indicate that gaps between arenas are not unusual, as it has been suggested that new scientific findings are not translating into new industrial products with sufficient speed to provide positive balances of trade (TFFAI, 2005). The inter-organizational networks that have emerged in the past two decades would appear to be developing in part to bridge these gaps between arenas. From a policy perspective, however, it is not a realistic option to rely upon the self-emergence of such networks. Further, the effectiveness of such networks is often asserted but not strongly documented, particularly with regard to exchanges of tacit knowledge.

When we shift to the problem of integration across sectors, it is likely that this requires a complex combination of associations to represent the interests of the different sectors and inter-organizational networks to ensure the transfer of technical information. This complexity begins to approach the kind of multiple problem-client delivery systems that have been studied and suggests the use of multiple coordination modes (Alter and Hage, 1993). Two important policy aims that would seem to require this complex kind of coordination mode are national security and global warming. Both of these imply the need for many new products and processes located in different sectors. In both instances, time is an extremely important consideration.

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In summary, the construction of new coordination modes is a relatively new topic for government intervention, at least within the context of the USA. Rather than emphasize the modes of state hierarchy or markets, we have instead discussed the virtues of inter-organizational modes and associations, especially as the latter allow for the negotiation of the different interests of the private and the public sectors.

Conclusions

The Innovation Systems Framework for RTD evaluation presented here responds to recent calls in the evaluation literature 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. If theory-led evaluations can determine what obstacles or blockages are preventing the realization of policy objectives, then policy-makers could begin the process of designing better interventions to achieve more effective innovation, as measured by our indicators of sector performance.

In summary, the Innovation Systems Framework represents a multi-level, systemic framework that has been developed through a comprehensive review and integration of the literature. While there is always room for improvement, we would argue that taking such an approach is an important step for evaluators and policy-makers to develop, implement and manage RTD investment portfolios and strategies more effectively.

Notes

1. The specific indicators for the identification of such issues, such as a lack of output in one or more arenas or, more critically, the lack of some societal outcome, are discussed in our other paper (Jordan *et al*, forthcoming).
2. For a more detailed discussion of the research profiles theory, see Jordan (2006; 2005) and Jordan *et al*, 2005.

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