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The Economics of a Technology-Based Service Sector

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EXECUTIVE SUMMARY

ES.1 INTRODUCTION

Technological change is an important stimulus to economic growth. Therefore, economic policy that promotes growth should address the conditions that facilitate the development and implementation of new technology. This report analyzes the sources and uses of advanced technology in the service sector, identifies barriers to more widespread use, and identifies policy options to ameliorate these barriers. In addition to the overview information, it contains case studies on the following key service sector industries: retail banking, home entertainment, and health care.

Effective technology policy recognizes the complementary roles played by the private sector, government organizations, and universities in creating a robust technological infrastructure that supports the development, diffusion, and implementation of technology. These organizations have widely varied objectives and incentives; still they must interact and collaborate to support the optimum level and pace of technology development and implementation.

Because technology development entails high levels of risk compared to other types of investment, economic policy generally supports some type of incentive structure. The most commonly proposed form is a broadly applicable policy, such as a tax incentive. More specific technology barriers often exist as well. These too are amenable to policy action. To formulate such actions requires a deeper understanding of the specific market environments in which the technologies are developed and applied.

The service sector is the largest and most rapidly growing segment of the U.S. economy. It accounts for roughly three-fourths of value added in GDP, and it has been growing at about 10 times the rate of the non-service sector. From 1984 to 1994, the U.S. economy grew 33.12 percent in constant 1987 dollars; service industries as a whole grew by 46.21 percent, while the non-service industries grew by just 4.63 percent. The service sector purchases large quantities of information technology and according to recent data is increasingly responsible for developing its own technology. In addition, the service content of “purely manufacturing” industries is increasing. More than 75 percent of a typical manufacturing firm’s employees are engaged in essentially service activities. So, increasingly, services are “pulling” technology development.

Despite the economic importance of the service sector, technology policy has not explicitly focused on this sector (though it is beginning to attract more attention). In part this lack of attention reflects the complexity of the sector, encompassing both very high-tech sectors (such as communication services and contract research services) as well as truly low-tech services (such as domestic services). In part, too, it reflects the conventional wisdom that the service sector, as a whole, is technologically unsophisticated. That belief has begun to change. This report supports the development of a technology policy for the service sector by assessing the height of the technology barriers facing service sector firms; exploring the sources of those barriers and the underinvestments they cause; and understanding how NIST can begin to address the most important of these barriers.

ES.2 TECHNOLOGY IN THE SERVICE SECTOR

By and large, the service sector is a consumer of technology rather than a developer of technology. While national statistics describe the steady growth of technology internal to the service sector — increasing from less than 5 percent of total R&D performed in the U.S. 15 years ago to 26.5 percent in 1993 — it appears that the bulk of this technology development is performed by the communications and computer services industries and that the typical service sector industry is far less active in R&D.

Far and away the dominant technology is information technology (IT). IT accounts for more than 80 percent of the technology purchased by service sector firms and is the predominant focus of service sector RDT&E (research, development, test, and evaluation) staffs. While some level of technology development is occurring throughout the service sector, it appears to be technologically diffuse and quantitatively modest.

In the service sector, as a whole, it appears more appropriate to speak of the RDT&E function of service firms than to speak of simply their R&D function. RDT&E staffs are small but growing. Corporate technology managers sense that such staff growth is a response to secular changes in the nature of their industries, such as the integration requirements that are the result of industry convergence and the movement toward integrating IT into service content and delivery. For large firms, an RDT&E group of 15-25 people is typical. Often, this staff coordinates the efforts of additional engineering and RDT&E staffs at the divisional level. The technical focus of 80-100% of the typical RDT&E staff is on information technology.

Besides traditional "R&D" activities, these staffs are also occupied with information gathering, research on potential vendors, pre-acquisition test and evaluation efforts, designing and monitoring of pilot projects, assessing and monitoring software service agreements, and evaluating the applicability of IT protocols developed by standards organizations.

What genuine R&D is performed in service sector firms often involves co-development efforts with hardware and software suppliers. IT is increasingly being applied to service delivery and content, in addition to traditional "back office" and "front office" operations. This appears to be stimulating more co-development efforts by service sector firms than in the recent past and the RDT&E staffs are becoming increasingly important. Our case studies suggest that service sector firms are especially concerned with research related to all aspects of the service provider - customer interface, from the hardware/software aspects (e.g., bank research efforts geared to biometrics to ensure greater security) to the "content development" aspects (e.g., entertainment company research on "how to appeal to the consumer's sense of exploration"). The literature also suggests that, increasingly, service sector firms must be concerned with R&D in the areas of human factors, psychology, and applications design that address the service provider-customer interface. As these technologies become an integral part of the basic service that firms deliver, internal control is perceived as more important.

In trying to explain the various ways in which technology is created and diffused, R&D policy researchers have developed models depicting the various relationships among technology developers and technology users. The model that most aptly captures the dynamics of the technology-based service sector is the "supplier-dominated" model.

Despite the fact that firms in supplier-dominated industries perform some internal R&D, their investments in new machinery and equipment, acquisition of hardware and computers, and manpower training are often more meaningful indicators of technological innovation than R&D spending alone. A concentration on process development rather than product development has been thought to be the root of similarities among supplier dominated industries (manufacturers or service providers).

Our analysis of technology development and implementation suggests that this model is flawed, or outdated, with respect to the service sector. There is a "phase shift" occurring in the application of IT in the service sector. The application of IT, once confined to "back office" functions, is migrating forward to service content development and delivery. This suggests a more dynamic model of technology development and use in which technology evolves from a process-orientation to a product-orientation. According to conventional wisdom, process innovations follow product innovations. In the service sector the opposite appears more typical. In the service sector, implementation of IT innovations has led to new, IT intensive, "product" offerings.

Service sector firms are relying more and more on developing collective approaches to addressing various technological issues. These take the form of formal collaborative R&D efforts involving suppliers of technology (typically in the manufacturing sector) and service sector users that are increasingly sophisticated in their understanding of the technology. More traditional institutions, such as trade associations, also provide an important venue for IT-related collective activity.

ES.3 THE TECHNOLOGY LANDSCAPE

In the three service industries examined in depth for this study, the pace of technological change is rapid and IT is effecting fundamental changes in industry structure and strategy. Yet the kinds of technology "roadmaps" that appear to serve an ordering and risk-reducing function in fast-paced manufacturing industries, such as microelectronics, are not being developed in service industries to our knowledge. There appears to be little industry-wide (not to mention sector-wide), systematic discussion of the technological division of labor (for example, between tiers of the industry, or among large and small firms within a horizontal industry segment), of the nature of the underlying technologies, or of the timing and level of technology investment by various key players.

Without a shared technological framework, at a minimum, it is extremely difficult to effectively conduct policy planning or communicate its results. For expository purposes, we characterize the following broad technology frameworks for the banking, home entertainment, health care industries:

- In retail banking three broad categories of technology development and application can be discerned:
  - Channel access technologies (by which banks gain access to their customer base)
  - Customer targeting technologies (by which banks analyze data for the purposes of defining financial services and targeting customer segments)
  - "Back-office" technologies (aimed at improving the efficiency of banking operations)

- In entertainment, three broad technology scenarios can be discerned:
  - — Technologies that emphasize entertainment (TV screens, remote control, excellent image and sound processing technologies, proprietary and specialized communications)
  - — Technologies that emphasize information (computer screens, keyboard interaction, communication via text strings, access through telephone modems)
  - — The merging of computer and TV technologies (teleputers, Internet communication)
- In health care, four broad categories of IT applications are recognizable:
  - — "Back-office" applications (maintenance and communication of medical services performed and billing)
  - — "Front-office" applications (maintenance and communication of patient health and treatment records)
  - — Health service content (the applications of IT to diagnosis and therapy)
  - — Health service delivery (especially on-line health services).

Within these technology landscapes, key infrastructure technologies have been identified. Each industry, indeed each firm, has a somewhat unique set of technologies, or technology implementation concerns, that are paramount. But some concerns appear to be common to all industries, even industries that are otherwise very different.

ES.3.1 Retail Banking

Of the three broad technology categories that are important to the banking industry (channel access technologies, customer targeting technologies, and "back-office" technologies) managers emphasize technologies that operate at the interface of the bank and the customer. Within the broad category of channel-access technology, bank security and network monitoring and control are stressed. Technology managers perceive these technologies as essential to building customer confidence about utilizing electronic channels.

Equally important in terms of customer confidence, though decidedly "behind the scenes," are the extensive testing and piloting techniques and procedures banks employ in preparation of IT implementation.

Because of the volume of transactions that could be affected, missteps or errors in implementation are carefully avoided.

The bank can be described as a physical network, with nodes and branches. Increasingly, the banking network has transformed itself into a physical network of interoperating electronic information systems. The future of banking appears to be a movement farther in this direction with an increasing need for interorganizational connectivity, first within the banking and financial services industries and, increasingly, with other segments of the economy as well.

The larger the network, the greater the benefit to the consumer of joining the network. So anticipating the consumer rush to the emergent standard service network, banks are precariously perched between advancing their proprietary positions (while solving the difficult integration problems that the continuous upgrading of legacy IT systems requires) and building a more open, interoperable, secure, and reliable electronic banking infrastructure that will promote consumer confidence and greater usage. Standard drawbacks to such an environment are underinvestment in experimentation and the rush by consumers to the standard solution rather than to the best solution.

ES.3.2 Home Entertainment

In the home entertainment industry, the development of new information and entertainment services is predicted to take place along two broad fronts associated with two families of user interface equipment: the television and associated technologies (set-top boxes and multimedia CD players) on the one hand; and information access via a general purpose personal computer on the other hand.

It is widely believed in the entertainment industry that for the foreseeable future computers and entertainment-oriented devices will continue to develop as related but separate digital system families, rather than converging into a single family. While the merging of the two into “information appliances” or “teleputers” is believed likely, most industry representatives considered it to be a decade away for the average household.

Underlying these technology scenarios are important technological trends in digital data transmission systems, digital data compression techniques, and multimedia hardware allowing steady decompression. These three technological areas, in turn, support a burgeoning market for home entertainment services: digital TV (HDTV, 500 channels, DBS, interactive TV); video games and multimedia CD players; on-line entertainment services; and digital audio.

Digital compression technology — specifically, “going beyond MPEG-2” with practical, widely adoptable standards — was perhaps the most consistently discussed area requiring technological advance. Compression technology appears to be important throughout the home entertainment value chain, from the expansion of programming channels through more effective use of limited (though rapidly expanding) bandwidth, to the conversion of large stocks of vintage analog film and the production of next-generation CD-ROMs (DVD technology).

Cable service operators were particularly concerned about network management, transaction-basis billing, and more effective video servers. The shift to new digital technology, and especially the preparation for video-on-demand, appears to be taxing conventional cable and broadcast operations.

Digital copyright protection is a pervasive and fundamental concern to the entertainment industry. Simply put, “[w]hen copies multiply, value collapses.” Industry observers are concerned about a near-future environment in which the memory and bandwidth exist to share any artistic creation as an e-mail attachment. As industry looks forward to video-on-demand, similar concerns are expressed. Further development and implementation of encryption technologies are of critical importance to the industry.

ES.3.3 Health Care

In the health care industry, IT is embodied directly in medical techniques and applications as well as in “back-office” and “front-office” information management functions. In many direct applications to medical problems, IT has been enormously successful. Such applications include the use of computer controlled beams of radiation to treat cancer, the use of high-speed computing to do computerized scanning and magnetic resonance imaging, and the use of IT to monitor the vital signs of patients.

The technologies currently important to health care organizations, and those technologies expected to be critical in the next five to ten years, show a strong emphasis on efforts to contain costs. There are immense data acquisition, communication, and storage problems to be addressed with IT. Clinical information systems are still very much paper based. One hospital might move 4000 patient [paper] charts a day and that is growing by the week. Long-term archival policies compound the problem.

The key problems within the health care organization are interoperating across large numbers of organizations — both within a parent organization and across independent organizations (such as the providers and the insurers) — and containing costs by figuring out a way to reduce all of the paperwork — that includes patients charts that are passed around in hospitals and it includes writing prescriptions and signing them. Exotic imaging tools and the like are in the works, but inter- and intra-organization interoperation and paperwork reduction are the critical near-term objectives for the productivity of IT in health care.

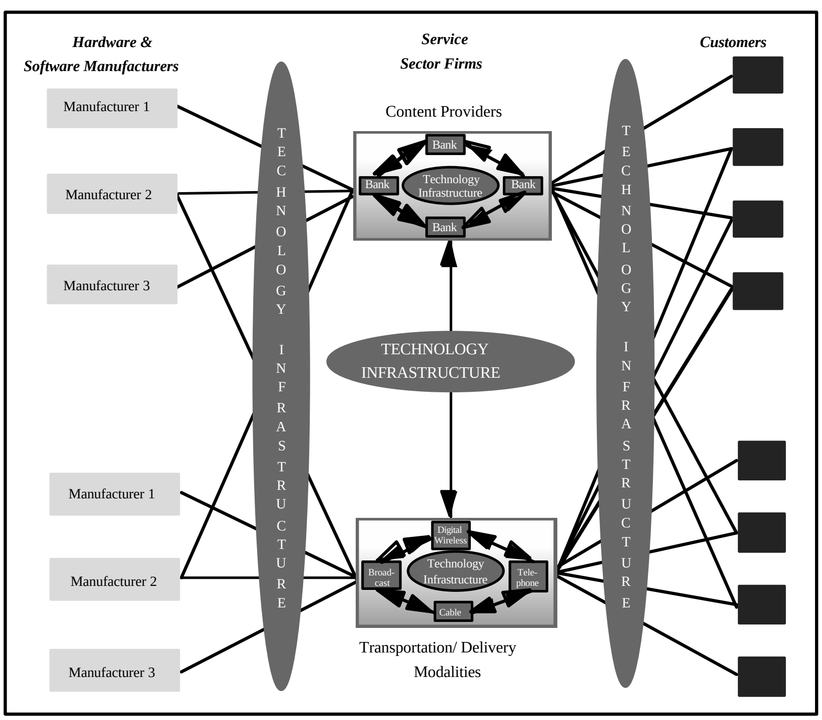
ES.4 THE TECHNOLOGY INFRASTRUCTURE

Diverse institutions play crucial, complementary roles in the development and implementation of complex technologies. Universities, private firms, government agencies, and collaborative organizations involving combinations of members from the various estates, develop technologies and interact on the basis of different types of incentives. As a result, technologies have both proprietary attributes, attributes that are public (i.e., non-proprietary), and attributes that are partly private and partly public (i.e., quasi-public or mixed). The technological elements provided by public and quasi-public organizations comprise a technological *infrastructure* which is both essential to technological progress and likely to receive too little investment if left to the private sector incentives alone.

The elements of the technology infrastructure can also be distinguished by the role they play in the process of technology development and market implementation. Two aspects of the technology infrastructure are of particular concern from NIST's perspective: "generic technologies" and "infratechnologies." Generic technologies are the laboratory-proven concepts that provide the immediate basis for research and development activities aimed at market-specific products (so-called, "applied" R&D). Functionally, generic technologies reduce uncertainty and technical risk enough to allow the magnitude of investment often necessary to bring technologically complex products and services to market. Infratechnologies, on the other hand, are shared "technical tools" such as measurement and test methods, reference materials, artifacts or data, that are used to verify the accuracy or quality of a process or output. Functionally, infratechnologies reduce market risks by verifying compliance with agreed upon standards and, increasingly, the physical or functional interface between components of a system. Infratechnologies provide the technical basis for industry standards.

The service sector's requirements for technology infrastructure are complex and comprehensive. Figure ES-1 depicts the three essential layers of the infrastructure that support technology development and implementation in the service sector. Technology infrastructure is required to support the interface between manufacturers and service providers; within the service sector to support the interface between service content providers and delivery modality providers (cable, telephone/Internet, broadcast, and wireless); and within individual service industries in support of the physical networks that characterize much of the service sector. The role of the technology infrastructure in the service sector is extensive, supporting the interaction of markets at many levels and at many stages of the value chain that runs from manufacturing to the final consumer. Within this framework, the provision of NIST's technology infrastructure occurs at both interfaces, for example, supporting increased interoperability through support for vertically organized generic co-development efforts, or the development of techniques and tools for assessing complex system-subsystem-component compatibility. At the service provider-customer interface, organizational processes (like the National ISDN Users), or infratechnologies to advance or characterize the security, reliability, and usability of service delivery technologies, are likely to be appropriate and desirable. The identification and support of infrastructure elements can mitigate the barriers that lead to market failure in several aspects of the service sector's development and use of technology.

Figure ES-1. Role of Technology Infrastructure in the Service Sector



ES.5 BARRIERS TO TECHNOLOGY DEVELOPMENT AND USE

The existence of barriers and market failures in the development and implementation of technology is the primary rationale for government involvement. Due to barriers that raise the risk and diminish the appropriability of investments in technology, the private sector sometimes fails to invest at a level and pace that is optimal from a societal perspective.

Three aspects of the IT revolution have been especially responsible for creating barriers to the development and implementation of IT: the convergence of different industries and technologies; the increased requirement for multi-faceted expertise and technical knowledge; and the rapidly evolving pace of technological change. These three themes are repeated over and over again in every phase of our investigations. In light of the systems nature of the innovation process and the frailties of the private market's incentive system related to innovative activity, these forces create a broad array of barriers that can, and do, lead to underinvestment in IT development and implementation.

Our statistical analysis of firm-level data clearly demonstrates that IT acquisitions are having a significant impact on firm performance. The results of this study indicate that a $1 investment in IT capital contributes substantially more to value added than a $1 investment in non-IT capital. Specifically, a $1 investment in IT capital yields $1.96 annually. These results imply that the rate of return on IT capital is 196 percent. On the other hand, a $1 investment in non-IT capital yields $0.11 each period, or a rate of return of 11 percent. This finding is interpreted to suggest that firms in service industries are, on average, realizing sizable returns on their investments in IT and that some non-financial barrier is preventing firms from making additional, highly productive investments in IT systems.

Service sector firms that systematically attempt to protect their investments in technology development, and those that participate in collaborative R&D activities, are investing more in IT capital than service sector firms that do not engage in such activities. While the statistical analysis is suggestive of further areas for research, even the best available firm-level data is insufficient to provide the detailed level of insight into technology barriers and their causes required for NIST strategic planning purposes.

Case studies of high-tech service sector industries — retail banking, home entertainment, and health care — allow the identification of specific technology issues that are important to industry growth and development and barriers that stymie their implementation. For selected technology areas, estimates of the underinvestments (hence market failures) that these barriers entail were developed. Estimates of the degree of underinvestment range from 20 percent to 300 percent of the current investment levels.

Bank executives describe planning horizons of no longer than 18 months, and health care technology managers describe the need for longer-term planning horizons to solve serious legacy system problems. They describe the gap between what is technically and physically required to provide IT-based operations, services, and service delivery, on the one hand, and what financial constraints impose, on the other. Estimates from health care technology managers suggest IT underinvestments of greater than 20 percent. These problems are compounded, in some cases, by overinvestments that were the result of "wildly inaccurate" projections of past waves of innovation.

These perceptions of high technological and business risk are the result of several phenomena that result in uncertainty about banking's technological future: the convergent nature of IT; the related fact that the locus of technological change is driven by forces outside the banking industry; organizational inertia in the banking industry itself; the inability to accurately predict customer response to "the networked bank;" and the host of technological issues that continue to confuse IT development and implementation planning: technology specific challenges, technology insertion, interoperability, security, and usability. The uncertainties caused by convergence are compounded by the systems nature of technology implementation in banking.

In health care and banking, pervasive legacy system integration problems are reported. Health care executives estimate that these problems cause IT underinvestments of 50% or more. The legacy systems problem is only one manifestation of a much larger system coordination problem that affects service firms and their customers as well. Technology managers across all industries express acute uneasiness in the face of rapid technological change and rapidly-evolving IT system choices. Bank executives, for example, express grave concerns about being "stranded" by investments in the wrong network technology.

The development and adoption of effective standards is regarded as critical in all our case study industries. Health care experts, for example, argue that in the absence of effective standards maintaining multiple formats for health care information, dealing with exceptions, and developing new interface software as new proprietary data management approaches come in and out of fashion all drive up costs and offset the potential savings from electronic processing of records and transactions. Electronic data interchange, for example, is not achieving rapid adoption because its benefits are understood to be contingent on a systemic change in health care practices and the development of integrated health service delivery systems. These are only beginning to emerge.

In banking too, a large number of formal and informal initiatives are underway to promote an effective infrastructure for Internet banking. Technology managers within the industry express concern that the formal standards process is not meeting their needs in this respect. Some 40 independent initiatives are currently underway to facilitate the evolution of a seamless electronic financial services delivery and payments environment.

In the home entertainment industry, cable service operators were particularly concerned about network management, transaction-basis billing, and more effective video servers. The realization of improvements in video server technology could double or triple investment. And the mitigation of barriers to the implementation of video-on-demand technologies could lead to additional billions of dollars of annual investment by cable network operators. Similarly, entertainment industry executives estimate that more rapid progress on next generation digital compression standards could unlock investments to support billions of dollars in the home video market revenues. Advances in data compression standards are expected to lead to investment by television broadcasters as well, as these technologies will enable additional programming while utilizing existing satellite transponder capacity. Entertainment industry technology managers project that improvements in Internet protocols would result in a 30 percent increase in related IT investments. Finally, digital copyright protection is a pervasive and fundamental entertainment industry concern. Industry representatives argue simply that as copies multiply, values collapse. Perceived inadequacies in digital copyright protection appear to be a source of technology investment barriers.

ES.6 KEY SERVICE SECTOR TECHNOLOGIES

Effective technology policy recognizes the complementary roles played by the private sector, government organizations, and universities in creating a robust technological infrastructure that supports the development, diffusion, and implementation of technology. Only through the interaction and collaboration of these diverse organizations, with their varied objectives and incentives, is the foundation created to support the optimum level and pace of technology development and implementation.

Table ES-1 shows some key technology areas which should be among NIST’s first priorities in developing a strategy to support the service sector’s technology infrastructure. The nature of the policy response (support for generic or infratechnology development) is also indicated. Given the complexity of the service sector and of the IT that supports it, some form of triage is essential to focus initial specific policy efforts. In-depth evaluation of the nature of infrastructure technology support should begin with technologies that are described as cross-cutting, in the middle column, and proceed to those described as inter-industry in the right column. Within each industry, there also appear to be technologies that are deemed uniquely important to a specific industry. While these too can entail important "public" elements, technologies that are more broadly applicable should receive priority attention.

Table ES-1. Cross-Cutting Infrastructure Technologies and Appropriate Policy Instruments

Appropriate Policy Instrument	Cross-Cutting Technologies	Inter-Industry Technologies	Intra-Industry Technologies
Support for Generic Research	• Electronic Commerce Applications	• Monitoring & Control for Large Networks • Set-top Boxes • Distributed Data Bases • Design for Speech Recognition Hardware/Software • Data Management • Systems Management • Systems Integration	• Operating Systems & Utilities (*Banking)* • Video Servers (*Entertainment*) • Hierarchical Mass Storage Systems (*Entertainment*) • Virtual Reality (*Entertainment*) • Techniques for Manipulating Unstructured Text (*Health Care*) • Visualization Methods for Complex Visual Information (*Health Care*) • Image Recognition & Processing (*Health Care*) • Scaleable Parallel Systems (*Health Care*) • Software Testing & Analysis Tools (*Health Care*) • Open Distributed Processing (*Health Care*)
Support for Infra-technology Development	• Cryptographic Standards • Firewalls and Internet-based Tools • Network Scaling • Data Compression • Wireless Communication	• WWW & IPv6 Security • Conformance Testing for Cryptographic Standards • Authentication Technology • Next-generation Internet Protocols • Multi-media Quality of Service Tools • Compression Algorithms	• User Interfaces & Information Access (*Entertainment*) • Multimedia Protocols (*Entertainment*) • Internet Security Policy Development (*Health Care*) • Vulnerability Analysis & Testing (*Health Care*) • Multimedia Collaborative Computing (*Health Care*) • Common Windowing Protocols (*Health Care*)

Consider the technology areas common to all three case study industries (column 1): electronic commerce applications, cryptographic standards, firewalls & Internet-based tools network scaling, data compression, and wireless communication. Of these, the private sector appears to have a dominant role in developing and implementing electronic commerce applications, but the fact that all three industries ranked this technology area as critical to their future suggests, at a minimum, some public policy concern to identify and address cross-cutting barriers (such as interoperability and security issues). Perhaps there are underlying generic technologies involved in electronic commerce applications that would be appropriate targets of collaborative research of the type supported by NIST's Advanced Technology Program. As part of a generic research effort in support of the service sector, such a program would aim at proposals that included vertically related partners, including representatives of service sector industries. In the other five technology areas, NIST information technology experts identify important issues appropriate to public sector involvement. In fact, NIST is currently engaged in the development and implementation of infratechnologies that support these technology areas, though, to our knowledge, these have not been focused or organized to support any special needs of the service sector per se.

While the high-priority technology areas common to retail banking and home entertainment — monitoring and control for large networks, set-top boxes, and distributed data bases — are the focus of much private investment, their priority ranking by representatives of two very different industries suggests that generic technologies and infratechnologies may underlie the effective service delivery strategies that these technologies support (column 2). Further evidence of the potential for a public sector role in providing infrastructural support for at least one of these technology areas (set-top box technologies) is suggested by intensive standards-related activities that have surrounded the regulation of interactive TV services. These activities pertain to the existence of complex systems of interfaces that can retard interoperability and timely adoption of technologies. Interactive TV technologies, such as set top boxes, are critically important to the service delivery strategies of services sector industries and firms.

The critical technology areas common to other service industry pairs (health care and banking, health care and home entertainment) more clearly involve technology areas in which NIST does provide infrastructural support (conformance testing for cryptographic standards, authentication technology, next generation Internet protocols, multimedia quality of service tools, and compression algorithms). Even where the proprietary role in technology development would appear to dominate (e.g., design for speech recognition hardware and software), the cross-industry nature of the priority accorded this and other technology areas (data management, systems management, systems integration) increases the probability that elements of generic technology are important to their fullest development and implementation.

Listed in column 3 of Table ES-1 are technology areas considered critical to members of single industries. These would be the lowest priority for technology policy initiative unless additional information allowed the selection of individual service sector industries as recipients of technology policy support.

It is very clear that across the service industries examined, the broadly defined technology areas of computer security (cryptographic standards, firewalls and Internet-based tools, conformance tests for cryptographic standards, advanced authentication technology) and networking (network scaling, data compression, wireless communication) are the dominant concerns of the service sectors. In both of these areas, NIST is already involved in providing technology infrastructure support.

Based on apparent overlaps in areas of technological interest, it appears that some community of technological interests exists between the entertainment, banking, and health care industries, with respect to technologies important to NIST.

In an attempt to understand service sector IT needs from a functional standpoint, industry technology managers were asked to rank five IT performance attributes. Table ES-2 shows their rankings of these IT performance attributes. The importance of usability and reliability across the sectors reflects some of the technical barriers service providers are facing as they attempt to implement new IT-based modes of operation and service delivery.

Table ES-2. Ranking of IT Performance Attributes by Industry

Retail Banking	Home Entertainment	Health Care
Usability	Interoperability	Usability
Security	Usability	Reliability
Reliability	Reliability	Scalability
Interoperability	Scalability	Interoperability
Scalability	Security	Security

ES.7 THE PRIVATE SECTOR RESPONSE TO TECHNOLOGY BARRIERS

Based on our case studies of service sector industries, firms are responding to barriers in at least four ways. First, they are investing considerable funds into coping with IT development and implementation barriers. The cost of IT implementation can be four to five the times the investment in hardware and software. Second, firms are increasingly investing in technology development, typically in the form of co-development projects with suppliers in the manufacturing sector. Third, they are engaging in collective R&D efforts with other members of their industry (though these, too, often involve manufacturing sector participants). These collective efforts are typically formed to gain access to complementary research or technical skills that are unavailable to individual service sector firms; they are less oriented to basic research than non-service sector collaborations; and often have standards- and protocol-related objectives (i.e., are more infratechnology focused), more so in fact than collaborative R&D projects undertaken in non-service industries. Finally, service sector firms are engaging in standards-related activities as a means of overcoming barriers to IT development and implementation.

All these forms of collective industry activity are attempts to address both technology-specific types of market failures (e.g., high risks due to technical complexity, requiring technical expertise not available to the firm) and market-related types of market failure (e.g. high transactions costs associated with systemic nature of IT that standards-related activities attempt to address). It appears that NIST's mission and expertise are highly complementary to the objectives of these efforts.

ES.8 THE PUBLIC POLICY RESPONSE: OVERARCHING ISSUES

A targeted technology policy that aims to support the development and implementation of IT in the service sector must address three overarching technology issues:

- Industry and technology convergence
- Service sector-customer interface
- System interoperability and security.

The industrial and technological convergence that is taking place in the service sector as a result of the IT revolution creates uncertainty among service providers and users. Corporate technology managers typically describe the technology landscape that they face as extremely chaotic. The uncertainty facing consumers is undoubtedly more intense than that facing professional technology managers and compounds technology investment barriers. Technology investment decisions by service providers are often “on-hold” in the face of both high risks and profound uncertainties arising from consumer ignorance about preferences in the face of rapid technological change.

The development of technology “roadmaps” (and the process that produces them) is an essential public policy tool and should go some distance in mitigating the intense technological uncertainty that pervades the service sector. The externalities associated with such an undertaking suggest a “public” role.

A second overarching issue concerns the design, development, implementation, and interoperation of technical customer interfaces. As IT is increasingly used by the service sector to develop and deliver service content, the importance of making these interfaces far more “user friendly” (appealing to all types of users), reliable, standard, and secure is apparent. And while the design and development of such interfaces may be largely a private sector responsibility, evaluation methods and techniques for assessing the quality of customer interfaces has important “public” aspects and could yield benefits across the service sector in terms of hastening customer acceptance.

NIST’s multi-faceted role in developing evaluation methods and techniques for assessing the quality of customer interfaces is likely to be an especially important aspect of NIST’s support of the service sector. This aspect of service sector IT implementation will have important benefits across the service sector in terms of hastening customer acceptance.

The third overarching issue that needs to be incorporated into an effective program to support service sector technology concerns the interoperability of forthcoming, current, and vintage IT software, components, and systems. Often referred to as “the legacy problem,” it is so widespread and costly, that any attempt to bolster the technology infrastructure of the service sector must address the issue. Clearly there are common problems in this regard within the same industries and, more than likely, there are common problems across industries. But to the extent that these common problems are being addressed individually by firms, or by industries where inter-industry solutions are possible, extra transaction costs are being incurred and less technology is therefore being acquired and implemented.

ES.9 THE PUBLIC POLICY RESPONSE: ENGAGING THE SERVICE SECTOR

NIST can play a potentially important and complementary role in the development of technology infrastructure supporting the service sector. Barriers to the more effective development and use of IT can be readily identified and NIST's policy tools — the development of generic technologies and infratechnologies — can contribute to their mitigation. Nevertheless we are still left with the question of how NIST is to engage the service sector in an effective manner.

Taking each of these issues in turn, NIST's Advanced Technology Program (ATP) has funded many generic technologies that are important to the service sector. It is a small step to identifying emerging technologies that are widely applicable to the service sector and encouraging their development. ATP already supports "focused programs" to advance the development and implementation of generic health care technologies. Other technological areas were identified that cut across a number of the industries covered in the case studies reported here, for example electronic commerce technology, speech recognition technology, and set-top box technology. ATP's approach to identifying generic technologies could be easily applied to cross-cutting technologies that could support the service sector more broadly.

Similarly, NIST has traditionally supported the manufacturing sector of the economy by participating in voluntary standards organizations through the development of the "tools," databases, and reference materials/artifacts that support performance assessment and conformance testing. In a technology-based economy, standards, and to a greater extent the infratechnologies that support them, are taking on increased importance due to the complexity of new products, the speed at which new models come into being, and the fact that these products are frequently embedded in systems whose effectiveness is, in turn, dependent on the interfaces between the components. Undoubtedly these infratechnologies are just as important — perhaps more so — to the development and implementation if IT for the service sector.

Planning a program of infratechnology support for the service sector poses an unparalleled degree of complexity. NIST's traditional approach of working through voluntary standards bodies is unlikely to prove effective in supporting the service sector for two reasons: one having to do with the evolution of IT and IT standards; one having to do with the nature of service sector as user rather than a developer of IT.

The pace of IT development and the ubiquity of IT applications has put the standardization system under pressures. Standards have become more urgent but consensus among interest groups is increasingly more difficult to achieve because of uncertainties associated with the pace of technological change. This dynamic has given rise to *functional standards* (e.g., Open System Interconnection - OSI) which define performance to be achieved at different layers of technological systems but retain some freedom in deciding how the standard will be met; and *anticipatory standards*, which are developed before the expression of the formal standard and before the onset of competition and its impacts on technology investment and adoption.

The relevance of anticipatory standards will depend on the ability of their developers to assess the potential outcome of ongoing research in the areas under consideration. Yet due to their anticipatory nature — anticipating demand and often the very existence of potential users — a distance has grown between IT producers and IT users. If the traditional standards process is a “post-marketing” function, involving marketing and engineering elements, increasingly the IT standards process is part of an R&D function that is by nature farther removed from the locus of relationships between sellers and buyers. That is, the locus of standards development activity for much IT has drifted upstream from the IT manufacturer-service provider nexus. This interpretation is consistent with case study observations that traditional standards organizations lack the focus and the flexibility to meet the needs of service sector firms, and with the emergence of collective industry organizations in response to various IT barriers.

The change in the pace and complexity of IT and its myriad applications, along with greater recognition of the importance of the quasi-public goods nature of certain technology elements, has caused several new types of ad hoc standards-related organizations to emerge. For example, Cooperative Research and Development Agreements (CRADAs) between government technology organizations and industry often have the early development of infratechnologies as their objective.

Other types of ad hoc organizations, such as research joint ventures (RJVs) and private consortia, have emerged as well, some expressly formed to bypass the formal international standardization process by delivering sponsored de facto standards ratification by the market. The integration of NIST core capabilities into these emerging IT-focused, collective organizations may provide critical infrastructural support to the service sector.

Across the service sector firms and industries we have studied, collaborative R&D mechanisms are being utilized to acquire the expertise needed to conduct IT-related research, develop specialized IT capabilities, and advance IT standards. In the banking industry, traditional industry associations are organizing special technology-focused efforts to rationalize diverse, overlapping, and potentially redundant technical development and standards-related activities. In many cases industry has expressed interest in exploring the participation of NIST.

These collective service sector activities are an important link in the overall development of the technology infrastructure that is increasingly important to the service sector. NIST can engage with these service sector organizations in ways that promote communications between IT users and the traditional IT standards organizations, while at the same time providing much-needed expertise in the analysis and anticipation of IT trends, in the evaluation of competing standards proposals, and in supporting the solution of other important cross-cutting technological issues that are stifling IT development and implementation in the services sector.

Such an orientation is consistent with the recently articulated strategic plan of NIST's new Information Technology Laboratory (ITL). ITL's strategy focuses on the development of measurement tools for impartially measuring IT products so that developers and users can evaluate how products perform and assess their quality. The strategy emphasizes involvement in early phases of standards development and specification development in advance of the formal standards process; support of informal standards groups (including industry consortia and professional societies) in defining and managing standards in a more precise and robust manner; and selected involvement with formal standards organizations where NIST's contribution can be significant.

ES.10 IMPROVING POLICY ANALYSIS: LESSONS LEARNED

Based on the investigations undertaken for this report and our experience with economic tools and data bases, we recommend important areas for additional research in support of NIST's service sector-focused strategic planning. First and foremost, additional case studies are in order. In-depth case studies are the only route to gaining the level of detailed understanding needed by NIST to support investment choices. Additional case studies would undoubtedly lead to an improved conceptualization and documentation of the role of the technology infrastructure in the service sector. For educational and public communications purposes, an improved conceptual model of NIST's role in supporting the service sector could be very important.

Another important area of research in support of NIST's service sector-focused planning should be directed to the theory and application of the concept of market failure. In our judgment, market failure is rarely discussed from the perspective of the buyer. Development of market failure concepts from a buyer's perspective would help clarify important issues and lead to better applied analytical tools.

Such tools are another important concern. For case studies of the quality (in terms of focus and depth) required by NIST, it would be very useful to develop "rule of thumb" metrics (not unlike the Hirshmann-Herfindahl Index used as an applied microeconomic analysis device in support of antitrust policy) that provide useful, though imperfect, insights under circumstances of relatively sparse detailed industry information. Relatedly, the development of a standard, easy-to-use methodology for generating estimates of IT underinvestment based on readily available accounting information would be very useful and could support priority ranking of industries for infratechnology support. In the conduct of case study surveys, it was often difficult to establish a baseline of information from which to derive underinvestment estimates.

To the extent that improved statistical estimates of the degree of underinvestment in the service sector are warranted, four areas of further research would add depth to the quantitative analysis contained in this report. First and foremost, public agencies need to collect much better data on the scale and nature of innovation in the service sector. Second, broader and deeper analysis of the role of RJVs in standards-related activities across the service sector would provide additional insight to the work reported here which focused on just one of the service sectors — communications services. Third, it would be useful to improve statistical models of service sector productivity by the addition of components that address the competitive impact of standards-related activities. Finally, the above models, and hence public policy, would benefit greatly from better characterization and measurement of the private and public elements that make up service sector technologies, as well as the interactions among these elements. It is these respective economic roles and their complex interactions that create the need for a public policy response.

1. INTRODUCTION

1.1 PURPOSE

This report is the first attempt to examine and understand the "technology infrastructure" of the service sector. This study has two explicit purposes. First, it aims to identify barriers to the development and implementation of technologies important to service sector firms; to understand why these barriers exist; and to assess the extent of the underinvestment these barriers cause. The second purpose is to suggest specific technology areas that are amenable to the policy tools at NIST's disposal, and to suggest the outlines of an initial course of action that will lead to the successful engagement of NIST and the service sector.

This study has an implicit purpose as well: to create a factual foundation for actions taken by NIST to support the economic vitality of the U.S. service sector. That foundation rests on: i.) an analysis of the Nation's innovation system and how the institutional components of that system respond to the various policy instruments available; and ii.) the application of the analytical concept of market failure. The former allows us to identify the core capabilities that NIST can bring to bear in addressing problems that retard the development and use of technology by the service sector. The latter allows us to identify those areas that would suffer from underinvestment by the private sector in the absence of efforts by NIST. Together they allow us to prescribe the most effective types of policy response for addressing the specific barriers to technology development and use encountered by service sector firms.

The investigation reported here was guided by the following three questions:

- Does the service sector's development and use of technology differ from other sectors? If so, in what ways?
- Are there barriers that are causing service sector firms to underinvest in technology and can we understand these barriers at a level of specificity that is appropriate to policy planning?
- Is there an appropriate role for NIST in supporting technology development and use in the service sector?

In brief, the answer to each of these question is affirmative. The diffusion of technology within the service sector differs from the pattern typical of the manufacturing sector in two major ways: for the most part the service sector depends on "imported" technology; and the nature of that technology appears to be primarily information technology (Chapter 2). The barriers to greater employment of technology are quantifiable (at a general level) and identifiable at the specific level (Chapters 4-8). Many of the important barriers to development and use of technology can be mitigated by the policy tools available to NIST (Chapters 8-9).

1.2 THE SERVICE SECTOR IS THE LARGEST, FASTEST GROWING SECTOR OF THE U.S. ECONOMY

The service sector is the largest and most rapidly growing segment of the U.S. economy. It accounts for roughly three-fourths of value added (GDP), and it has been growing at about 10 times the rate of the non-service sector. From 1984 to 1994, the U.S. economy grew 33.1 percent in constant 1987 dollars; service industries as a whole grew by 46.2 percent, while the nonservice industries grew by just 4.6 percent. The dominance of service sector can also be seen in employment data. Between 1984 and 1993 employment increased 23.6 percent in the service sector and decreased 4.4 percent in non-services. (U.S. Department of Commerce, July 1995b; U.S. Department of Commerce 1988, 1994).

Growth in the service industries is shown in Figure 1-1 by observing each industry's proportion of nation-wide value added at both the beginning and the end of the period 1984-94. In 1984, the nonservice sector was 31.5 percent of the U.S. economy, while services constituted 68.5 percent. By 1994, the nonservice sector created 24.7 percent of the economy's value added, while services provided 75.2 percent. All nonservice industries have seen their share of the economy fall from 1984 to 1994, with the largest nonservice sector, manufacturing, falling from somewhat more than 22 percent to less than 18 percent of the economy. Among the service industries, the finance, insurance, and real estate industries and the collection of "other private services" have grown dramatically as a proportion of the economy, with the remaining service industries becoming somewhat smaller as a proportion of the entire U.S. economy. (U.S. Department of Commerce July 1995a; U.S. Department of Commerce 1988)

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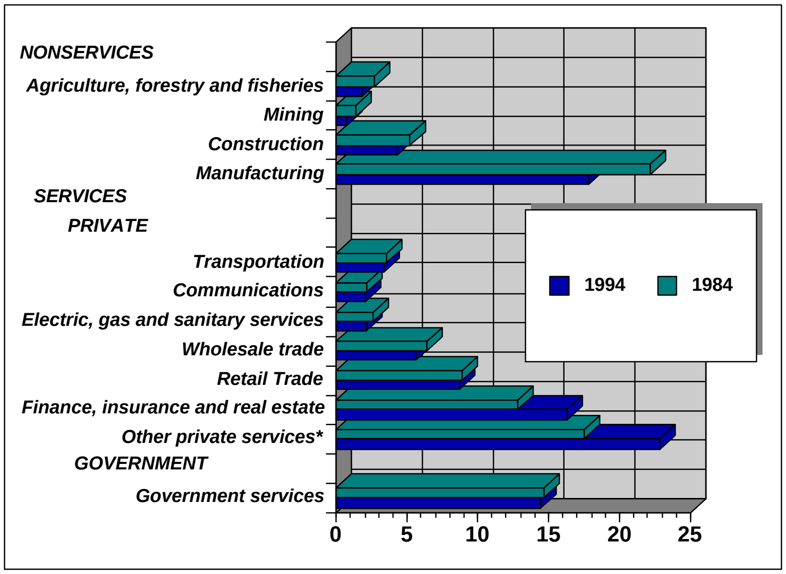
Figure 1-1. Industry Percentages of the U.S. Economy by Value Added



Sources: U.S. Department of Commerce, *Survey of Current Business*, July 1995, Vol. 75, No. 7 (Washington, D.C.: U.S. Government Printing Office, 1995). The data for 1994 value added are from Table 6.1C, "National Income Without Capital Consumption Adjustment by Industry, Domestic Industries," p. 18. U.S. Department of Commerce, *Survey of Current Business*, July 1988, Vol. 68, No. 7 (Washington, D.C.: U.S. Government Printing Office, 1988). The data for 1984 value added are from Table 6.3B, "National Income Without Capital Consumption Adjustment by Industry, Domestic Industries," p. 79.

A more detailed breakdown of the service sector would show that the growth within "other private services" has come in several areas. Health services is the largest industry in this category and it showed substantial growth, but several other categories have grown substantially as well, among them hotels and other lodging places, business services, auto services, motion pictures, amusement and recreation services, legal services, educational services, social services, membership organizations, and engineering and management services. (U.S. Department of Commerce 1994; U.S. Department of Commerce 1988)

The service sector is extremely complex; including some of the most technologically advanced industries in the economy as well as some of the least advanced. Despite its importance to economic growth and development, the service sector is not well understood. While some useful generalizations about the role of technology in the service sector can be gleaned from available statistics, little information specific enough for the formulation of effective technology policy is readily available. For example, the fastest growing industrial grouping, “other private services,” arguably contains some of the most dynamic industries in the service sector. But these dynamic industries are embedded (for statistical purposes) in this broadly defined statistical grouping, making it impossible to use standard data to identify industry-specific status, trends, and solutions. For this and other reasons, experts believe that the service sector has been largely ignored in the national policy discussions concerning U.S. international competitiveness. (Quinn, 1992)

1.3 THE ROLE OF TECHNOLOGY IN THE SERVICE SECTOR

The service sector itself is not well understood, and has long been virtually ignored in general economic policy discussions. It is therefore not surprising that policy discussions concerning the role of technology in the service sector have received little attention. In part this has been due to a widespread misconception that the service sector is unworthy of serious policy attention. According to leading service sector experts:

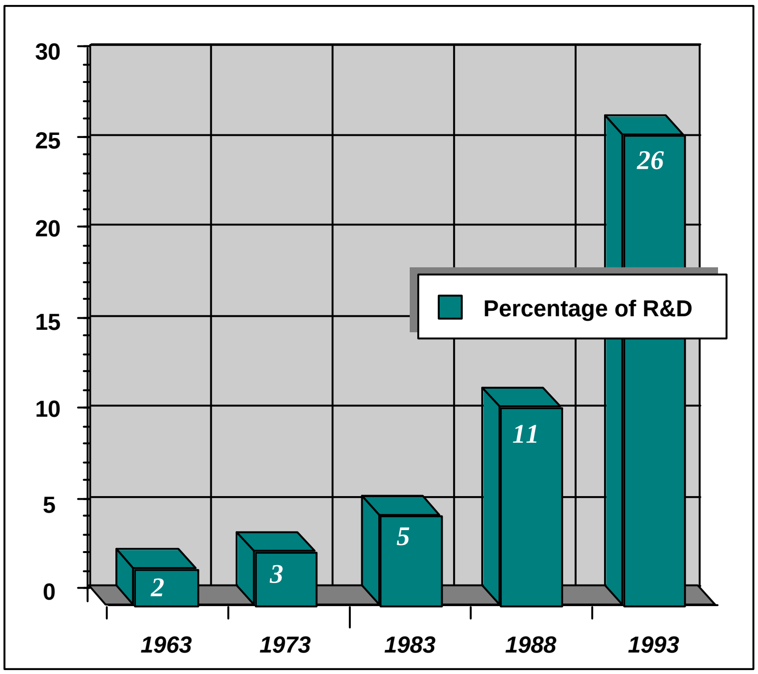
> Contrary to the widespread misconception of services as predominantly simple, labor-intensive activities, the service industries include many large, technology-intensive and technically sophisticated firms in transportation, financial services, banking, insurance, retail and wholesale trade, telecommunications, health care, and professional and personal services. (Quinn et al., 1994)

This perception is beginning to change. A recent high-level review of U.S. technology policy describes the technological dynamism of the U.S. service sector and observes that the growth of the service sector has not been reflected in U.S. technology policy. (Executive Office of the President, 1996) This report is an important step in the direction of a well-grounded technology policy to support the service sector.

Given the importance of the service sector to U.S. economic growth and the belief that technology is the driver of economic growth, it is vitally important to understand the sources and roles of technology in this sector. Technology is either developed within a firm or industry or it is acquired, often in the form of “embodied technology” contained in purchased equipment. Both sources of technology are important to the service sector. We conservatively estimate that 83 percent (by value) of all technology “imported” into the service sector is information technology (IT). Implementation costs are estimated to be 5 times greater than hardware costs alone.

Internal technology development is increasingly important to the service sector.[1] National Science Foundation (NSF) data provide an overview of the size of R&D activity in service industries as compared with the rest of the economy. As shown in Figure 1-2, manufacturing is still the leading performer of R&D in the U.S. economy. U.S. Department of Commerce (July 1995b) and U.S. NSF (1996) show that manufacturing originates just 17.8 percent of the economy's value added yet performs 73.5 percent of total R&D. Services originate 75.3 percent of value added, and perform most of the 26.5 percent of total U.S. R&D performed by nonmanufacturing.

Figure 1-2. The Share of Nonmanufacturing Industries in Economy-wide R&D Expenditures (1963 to 1993)



In addition to the growing importance of the non-manufacturing sector in U.S technology development activities, it also appears that the nature of the technology being developed across the economy is increasingly less specific to manufacturing and manufactured products. This finding is based on an analysis of all U.S. patents between 1981-85 and 1991-96. Between these two periods, patents classified as non-

1 As shown in Chapter 2, the technology development within the service sector appears to be concentrated in the communication services and the computer services industries.

manufacturing specific increased 23 percent, from 22 percent of all U.S. patents in the first period to 27 percent in the current period.[2] In part, this reflects the fact that even while the manufacturing sector dominates technology development activities, the service content of manufacturing activities is itself increasing. According to a leading management consultant:

> The average manufacturing company today ain't [sic]. Seventy-five percent to 95 percent of a "manufacturing firm's employees are in non-manufacturing activities - engineering, design, sales, marketing, information systems, purchasing, service, distribution. That is, they are in the professional-service development and delivery "business." (Quinn, 1992)[3]

Both the increasing prominence of the service sector and the interdependence of manufacturing and services are reflected in the flows of products and services between the two sectors. As shown in Figure 1-3, services are increasingly important inputs to the production of goods as well as services:[4] the amount of service inputs needed to deliver $1,000 worth of final goods or services increased by $79 between 1977 and 1987. Moreover, the requirements for non-service inputs declined by $150 during the same period. And while the average increase in demand for service inputs as a whole increased 8.3 percent between 1977 and 1987, requirements for service sector inputs by specific industries rose dramatically. The "computer and office equipment" industry, for example, registered a six-fold increase in its demands for services between 1977 and 1987. (U.S. Department of Commerce, 1996)

1.4 THE TECHNOLOGY INFRASTRUCTURE

Technology is the most important ingredient in the formula for economic growth, accounting for more than one-half of the long-term rate of increase in an industrialized economy's output of goods and

---

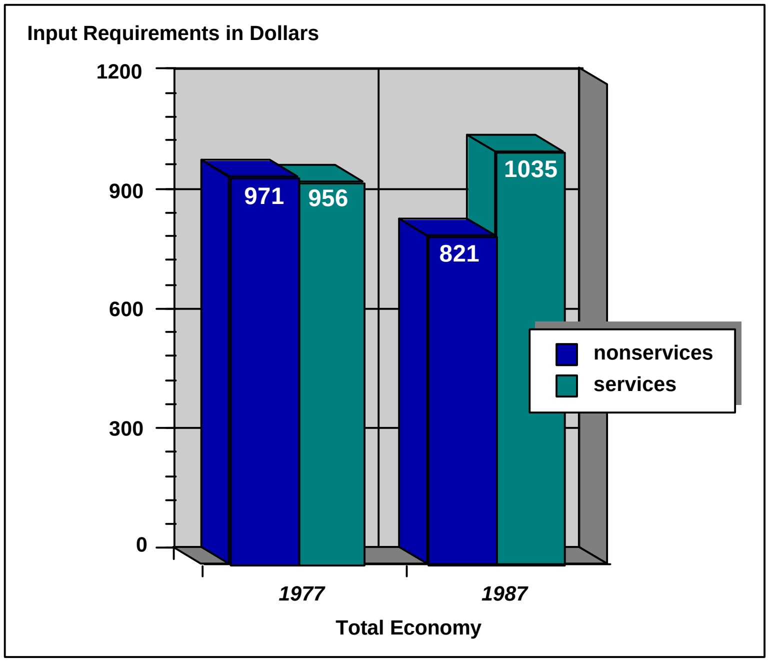
2 The manufacturing/non-manufacturing patent segmentation was performed by CHI Research, Inc. To segment the population of all U.S. patents granted from 1981 to 1990 into two categories (manufacturing specific and non-manufacturing specific), CHI Research, Inc. utilized the International Patent Classification (IPC) code. IPCs were categorized as manufacturing-specific, non-manufacturing specific, and hybrid. A list of the IPCs contained in each category is available upon request.

3 This quotation is from management consultant, Tom Peters. It is taken from the foreword to Quinn (1992).

4 For those unfamiliar with reading input-output tables, the following question might be posed of Figure 1-3: "How can it take in 1987 $1,035 in services and $821 in non-services to deliver $1,000 worth of goods and services?" The answer is as follows. In an input-output context, output of an industry is used either as an input by other industries or is sold directly to the final consumer. So for every $1,000 of final demand, the economy (in 1987) produced $1,856 in gross output ($1,035 of which was produced by service industries and $821 by non-service industries). The additional $856 in output was used by other industries as intermediate inputs. So the double-counting of the value of intermediate inputs explains why it appears to take more than $1,000 of services and non-services to provide $1,000 worth of goods and services.

services. (Tassey, 1995) The Economic Report of the President (1997) recently referred to research and development as a "pillar of growth" leading to "greater economic efficiency". So economic policy that aims at fostering growth (and the rising incomes and employment opportunities that come with economic growth) must, at the same time, aim at fostering the development, diffusion, and implementation of new technology.

Figure 1-3. Input Required to Deliver $1000 of Goods and Services to Final Demand*



*Weighted average based on Bureau of Economic Analysis 1977 and 1987 Input-0utput tables (1987 final demand weights).

Source: U.S. Department of Commerce (1996).

To understand the policy implications of the increasing technological sophistication of the service sector requires that we first understand how technology influences economic growth and identify the various institutional actors in our Nation’s system of technology development and implementation. With such a framework before us, we can begin to ask the really important policy questions posed by a technology-based service sector. These policy questions, in turn, drive the analytical objectives of the study.

Researchers and policy makers are becoming aware of the various institutional components of the nation's innovation system and the respective, complementary roles that government, business, and universities play in the "production" of technology and in the implementation of technological change in the interest of competitive advantage.[5] The resulting technology has proprietary attributes; attributes that are public (i.e., non-proprietary) in nature; and attributes that are part private and part public (i.e., quasi-public or mixed). It is the public and mixed attributes that give certain elements of industrial technology an infrastructural character and it is these attributes that make it likely that the private sector will underinvest, from a societal point of view, in the public or quasi-public attributes of technology. These underinvestments, in turn, are supplemented by technology and market-specific programs to bolster technology development and market development activities.

According to Tassey (1997), technology infrastructure is defined as:

> [A]n element of an industry's technology that is jointly used by competing firms. One category of this advanced infrastructure is what has come to be called an industry's generic or fundamental technology.[6] A second category of technology infrastructure includes the various techniques, methods, procedures, etc., that are necessary to implement product and process strategies [all of which trace back] to a set of generic underlying principles.[7] A third category of technology infrastructure consists of a set of technical tools for making the entire economic process more efficient, or, in some cases, possible in the first place.[8] Collectively, these tools are called infratechnologies.

A disaggregated model of the innovation system is depicted in Figure 1-4. In this model, innovation is derived from a number of different technological inputs and from a variety of institutions. The collection of technology inputs marked off in the box at the lower left corner of the figure — proprietary technologies, generic technologies, infratechnologies, and science base — are of particular concern because non-market actors and unconventional market forces have varying degrees of impact on these inputs. For example, the development of generic technologies is a typical objective of research consortia, organizations formed with

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5 For further discussion of the "systems" or "network" nature of the innovation process see: Link and Tassey (1987), Porter (1990), Tassey (1992), and Lundvall (1992).

6 A generic technology embodies laboratory-proven concepts, but not the subsequent market-specific products and processes. For example, demonstrating in the laboratory that the *generic concept* of a ceramic engine can operate at higher output per unit weight with improved gas mileage and lower pollution than a metal alloy engine is a long way from mass production at reasonable cost.

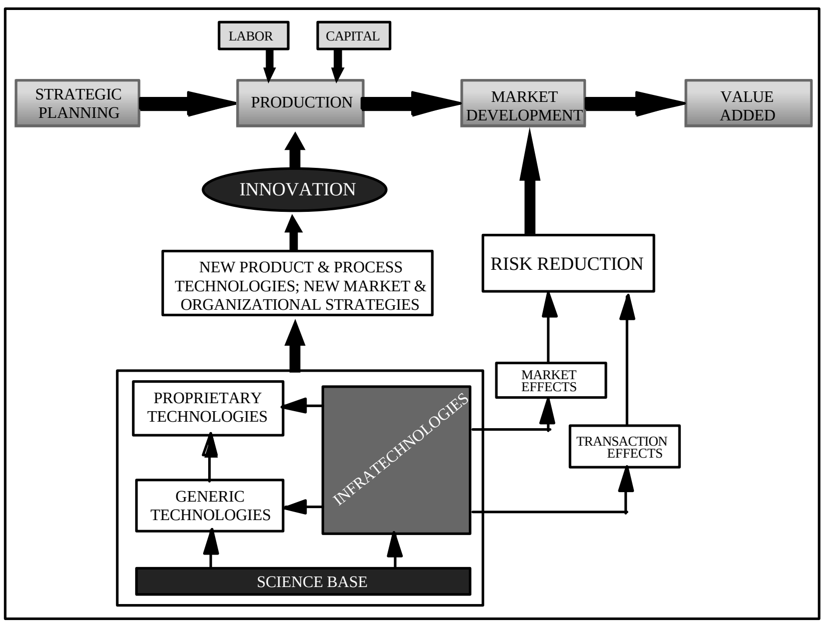
7 Total Quality Management (TQM), for example, falls into this category.

8 Standard reference materials (SRMs), standard reference data (SRD), and test methods, for example, fall into this category.

increasing frequency to supplement the incentives available to individual market actors. The growing prominence of these organizations as vehicles for industrial R&D represents the market failure phenomenon at work in the sense that in many cases whole research programs, involving scores of commercially significant research projects, would probably not have been undertaken — in the absence of these collective organizational mechanisms — on the basis of market incentives available to individual firms alone.[9]

The public sector has played an important role in many of these consortia as substantive technical contributors and as sources of finance, both directly and through government support to universities which are often involved in consortia as well.[10]

Figure 1-4. A Technology-Based Economic Growth Model



Source: Tassey (1997, Chapter 4)

The role of basic science is also depicted in Figure 1-4. The development and dissemination of basic scientific understanding, common to all technological development, has long been considered the role of publicly funded colleges and universities. Recent evidence suggests that, in fact, the results of this

9 See Hagedoorn (1996), Link (1996a), and Baldwin (1996).

10 See Link and Tassey (1989).

publicly funded research tends to be more broadly applicable (basic) and less commercially appropriable than corporate research. [11]

So-called "infratechnologies" have special importance in this study because NIST has a special role in identifying barriers to the development and implementation of technology that can be addressed through the development and diffusion of infratechnologies. While infratechnologies are provided by public as well as private organizations, they are believed to be underfunded by the private sector, requiring public support. A less widely recognized component of the national innovation system, infratechnologies include evaluated scientific and engineering data used in the conduct of R&D; definitive measurement and test methods used in research, production, control, and acceptance testing for market transactions; various technical procedures, process models and techniques; and interface standards.

Taken together, all these components of the national innovation system — basic research, infratechnologies, generic technologies — serve as a technology infrastructure and support private sector R&D investment in specific products and processes. Much as the national transportation system facilitates the flow of goods and services in the economy at large, so too the *technology infrastructure* facilitates the creation and flow of technology development and implementation activities. And just as public sector investment in the transportation infrastructure is essential to the productivity of the economy, so too investment in the technology infrastructure is an essential element of an effective innovation system.

1.5 THE TECHNOLOGY INFRASTRUCTURE OF THE SERVICE SECTOR

Information technology (IT) is at the heart of technological change in the service sector. It has even been suggested that the technological and industrial dynamics that have resulted from the growing prominence of IT have caused the emergence of a system of complementary public and private institutions, described above as providing the Nation's technology infrastructure, from the ashes of the "old innovation system" dominated by large centralized corporate labs. [12]

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[11] See Trajtenberg, et al., (1993).

[12] See, Christopher Freeman, "Formal Scientific and Technical Institutions in the National System of Innovation," pp. 169-187, in Lundvall (1992).

Three aspects of the IT revolution have been particularly important in creating challenges for service sector technology managers: the convergence of distinctly different industries and technologies; the increased requirement for multi-faceted expertise and technical knowledge; and the rapidly evolving pace of technological change.[13] These three themes are repeated over and over again in every phase of our investigations. They are among the defining characteristics of the IT paradigm which service sector firms appear to be adopting. In light of the systems nature of the innovation process, and the frailties of the private market's incentive system as it pertains to innovative activity, these forces create a milieu of barriers that can, and do, lead to under-investment in IT development and implementation.

This report represents the first attempt to examine the technology infrastructure of the service sector. The model shown in Figure 1-4 helps in two different ways: it presents a guide to the investigation of barriers to technology development and implementation, and provides a benchmark for understanding the sources and uses of technology in the service sector. What is the level, scope, and nature of proprietary research and development efforts in the service sector? What new organizational forms and programs are being dedicated to the development and dissemination of generic technology? What kinds of "infratechnologies" are fundamental to the development and growth of the service sector? Are these infratechnologies readily available or, as expected, do we find them underdeveloped due to their quasi-public character? To what extent are the activities and outputs of the entire network of private, public, and private-public technology activities being coordinated to positively influence the commercialization of goods and services and the global struggle for market share?[14]

As a benchmark device, we ask, "How should this model be altered (if at all) to account for the dynamics of technology development and implementation in the service sector, or particular industries within the service sector?" Unlike the manufacturing sector from which our model of technology infrastructure is derived, the service sector is largely (but certainly not exclusively) supplier dominated. That is, despite the rise in "internal" R&D, the service sector still acquires the vast majority of its technology "embodied" in purchased equipment and software.

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[13] See Perine, et al., (1996).

[14] For answers to these and many related questions for the manufacturing sector see Tassey (1992) and Leyden and Link (1992).

Nevertheless, service sector firms are deeply engaged in technology-related activities in the form of test, evaluation, and implementation of technology developed outside the firm and in co-development efforts as “lead users” of technology. Part of the evaluation efforts of service sector firms are devoted to the development and assessment of standards and protocols being developed outside the immediate purview of the service sector firms. Increasingly, we believe, service sector firms are directly developing technologies and engaging in standards-related activities to meet their specific needs. As lead users, service sector firms (other than communications services and computer services firms) are involved in technology development activities as traditionally defined. These co-development efforts are undertaken to guide and leverage the ongoing technology activities of traditional technology producers in the manufacturing industries. There is a sense that this is an increasingly important function and that service sector firms are increasingly participating in this kind of technology activity.

Another prominent feature of service sector technology is its systems nature. Information technology is the predominant form of technology being used and developed in the service sector and this technology is being used to increase process efficiency and to develop and deliver services. All of these functions require complex and demanding system integration efforts that involve multiple units within the same organizations; integration among service providers; and integration between service providers and a large and diverse population of end users. On the “back-end,” service sector providers need to integrate “incoming” technology from numerous vendors.

So while the technology-based growth model depicted in Figure 1-4 serves to identify the component parts of the innovation system, and the various functions these components serve in reducing barriers to technology development, implementation, and the creation of value in the market place, the systems integration aspect of the technology that so dominates the role of technology in the service sector is under-emphasized. Figure 1-5 attempts to capture the above essential features of technology implementation in the service sector and to show the locus of technology infrastructure requirements.[15] (The specific infrastructure roles of generic and infratechnologies in the service sector are discussed in Chapters 5-9 of this report.)

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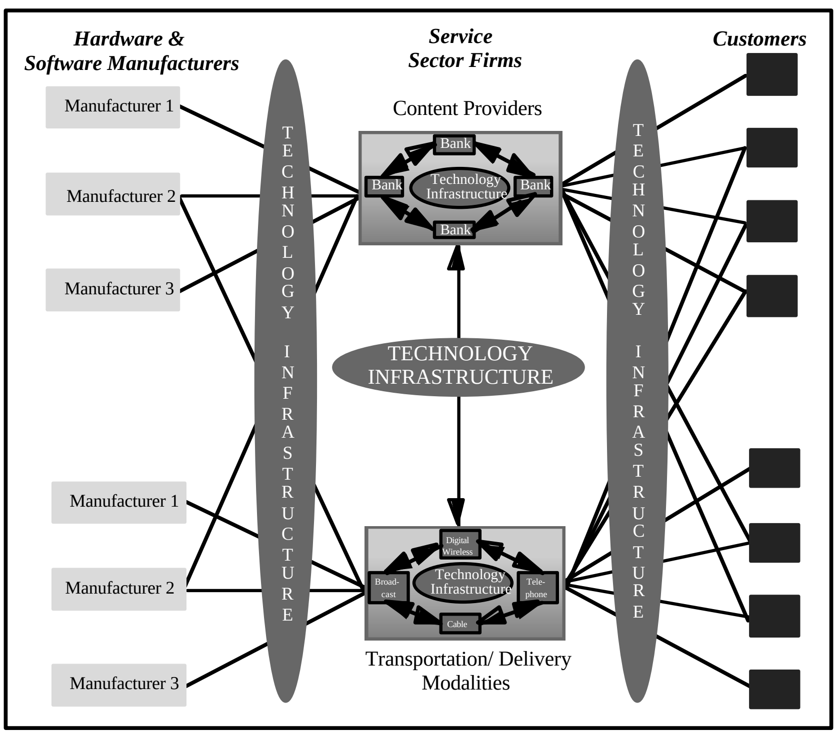
[15] The depiction of technology infrastructure shown in Figure 1-5 is consistent with the model of service sector technology infrastructure developed by Tassey (1997).

1.6 THE OUTLINE OF THE REPORT

Chapter 2 provides a characterization of the technology developed in and used by the service sector. It emphasizes the relative importance of information technology (IT) in this sector and provides estimates of the scale of internally developed and "imported" technology. Information concerning the chief performance characteristics demanded of purchased technology and its competitive significance is presented.

Chapter 3 develops the concept of market failure and describes numerous economic phenomena that can create barriers in the development and implementation of technology. Each barrier is described and illustrated with an example drawn from the trade press concerning the

Figure 1-5. Service Sector Technology Infrastructure



utilization of technology in the service sector. This chapter also discusses the policy instruments that are best suited to mitigate the various types of barriers. Finally, Chapter 3 also explores technical performance barriers to the implementation of technology from a service provider's perspective and characterizes the prevalence of these performance barriers based on a systematic review of technical trade literature.

Chapter 4 presents the results of a statistical analysis of firm level data that estimates the scale of service sector underinvestment (market failure) in IT and explores the effectiveness of selected strategic responses to market failure.

Having quantified the scale of service sector market failure with respect to IT and tested our ability to assess policy responses based on statistical analysis tools, Chapters 5 through 8 present case studies of three service sector industries (retail banking, home entertainment, and health care), identify weaknesses in the technology infrastructure supporting these industries, and develop cross-cutting policy concerns. Chapter 9 develops an analysis of the institutional framework that supports the technology infrastructure for the service sector; extends the "Tassey model" of technology-based economic growth to the service sector; and suggests the broad outline of a strategy through which NIST can engage the service sector.

2. SOURCES AND USES OF TECHNOLOGY IN THE SERVICE SECTOR

2.1 ALTERNATIVE SOURCES OF TECHNOLOGY

Broadly speaking, technology is the application of knowledge. With individuals, knowledge comes from myriad sources. Formal education is one form of acquiring knowledge, but knowledge can also be gained experientially. Further, each source of knowledge can augment the human capital of individuals differently. So it is with an organization's technical knowledge. There are alternative sources for acquiring technical information, and each source can augment the production or service delivery processes differently.

One can broadly characterize sources of technical information as being either internal or external to the firm.[16] The most obvious internal source is in-house research, development, test, and evaluation (RDT&E) activity. External sources of technical information are more varied. One important external source is other firms; firms acquire technology that is embodied in purchased capital equipment.[17] In the case of IT hardware purchased by service industry firms, a significant of in-house RDT&E is devoted to implementation. While the service sector has been increasingly responsible for internal technology development, so far as technology is concerned, the sector is still best categorized as supplier-dominated.[18]

2.2 FOCUSING ON INFORMATION TECHNOLOGY (IT)

2.2.1 Existing Literature

Given that the term “service sector technology” is effectively limitless, to focus the research effort we asked if areas of technology concentration could be discerned that are broad enough to be meaningful for a discussion of technology policy in support of the vast service sector, but narrow enough to be

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16 One review of the history of the "make versus buy" literature is in Bozeman and Link (1983).

17 There are other important external sources. The federal government is one important source (Tassey 1995.) Firms involved in either contracted research or cooperative research and development agreement (CRADA) relationships can appropriate technical information from their project involvement. A second source is universities. Firms appropriate technical knowledge from universities by funding participation in university-based research, or by hiring graduates. A third source is other firms, domestic or international. Firms can also acquire technical information directly through mergers, or indirectly through their participation in collaborative research relationships. Another important external source of technical information is informal inter-organization communication between technical personnel (vonHippel 1988). Finally, firms can license technology from other firms.

18 The concept of a supplier-dominated variation of Tassey’s technology-based economic growth model (described in Section 1.4), and its appropriateness for the service sector, is discussed in Chapter 9.

somewhat exclusive. Previous research had focused on the role of "information technology" in the service sector.[19]

To verify the validity of this focus, we conducted an initial review of trade literatures.[20] This review added weight to the hypothesis that IT — broadly defined — was indeed the focus of much industry discussion and concern.[21] An unbiased review of the general trade press indicated that service sector concerns about technological change is overwhelmingly IT-oriented. Across the broad service sector industries — transportation, communications, utilities, wholesale & retail trade, finance, insurance, and real estate, educational services, hotels, health services, and business services — the preponderance of articles discussed the development and implementation of communications technologies, networking, integrated messaging, next generation Internet development and applications, on-line service provision, voice and data network enhancements, electronic catalogs, desk-top conferencing, e-mail, open system information solutions, talking menu boards, computerized registration systems, telemedicine, and teleshopping to name but a few specific areas of interest. While non-IT technologies (e.g., multipurpose vehicles, hardware devices, architectural design research, video server and computer hardware) were discussed, the overwhelming focus in the trade literature concerned with "technological change in service industries," discussed information technology for improved operational efficiency and for the creation of new services.

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19 For in-depth treatments of these various aspects of the service sector's role in the economy, and the role of information technology in service sector industries, see Quinn (1992, 1994), and U.S. Department of Commerce (1996).

20 The methodology used to select the population of literature articles was in no way biased to report IT-related technologies. We interpret the results to be indicative of the primary technological focus of service sector firms. An electronic search to find recent articles related to technological change and services was conducted. ProQuest's ABI/INFORM Global CD for January 1994 through November 1995, as well as CDs covering earlier literature during all of 1992 and 1993, was searched for articles using a variety of keywords such as "technological change" and "service industries", "innovation" and "services industries" and so forth.

21 Although there is not a formal, generally accepted definition of information technology, we use the term to refer to traditional communications and computational technologies as well as technologies emerging due to the analog to digital shift in information dissemination and representation. According to IT specialists, information technology is still evolving as a distinct category of technology due to an ongoing convergence of two distinctly different industries, communications and computing. Advances in digital technologies have eroded the demarcation between the historically analog communications world and the digital computing world. And despite the fact that communications technologies were firmly entrenched in incompatible analog systems, the digital basis upon which the computing world was built is expanding to encompass the formerly analog technologies of telephone, broadcast, cable television, wireless communication, and satellite transmissions. (Perine et al., 1996)

2.2.2 Other Systematic and Quantitative Data

Other systematic data support a focus on IT as well. Based on the National Science Foundation data presented in Table 2-1, a majority of the R&D activity in service industries appears related to information technology. Communication services (SIC 48) accounts for 17.5 percent of the total R&D and 15.5 percent of the R&D scientists and engineers in the non-manufacturing (mostly services) sector.[22] Computer related services (SICs 373, 871) take 32.2 percent of total non-manufacturing R&D and 38.2 percent of R&D scientists and engineers.[23] Computer-related services account for about 4.1 percent of private service's value added and 2.8 percent of private service's full-time equivalent employees.[24]

Thus, a lower-bound estimate is that 49.7 percent (49.7% = 17.5% + 32.2%) of service sector R&D is by communications services and by computer-related services firms. Because IT is becoming a critical element of the activities of these two industry segments, we conclude that 49.7 is a reasonable approximation of the percentage of service sector R&D directed to information technology. (Perine, et al, 1996) And, to the extent that R&D in other service industries is devoted to information technology as well, 49.7 percent may be a lower-bound approximation.

Patent data provides another window onto the technology activities of service sector firms. We know from the NSF data presented in Chapter 1 that the service sector's share of total R&D is rising. Patent data is the only readily available, systematic source of detailed technical information that provides a window onto the specific content of firms' technology-related activities.[25]

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22 These percentages were calculated as follows. Total non-manufacturing R&D from Table 2-1 is $31,321 million ($5,491+$339+$10,092+$132+$2,084+$13,183 million). Communication services ($5,491 million) is 17.5 percent of this total. Similarly, the total number of scientists and engineers employed in non-manufacturing is 190.8 thousand (29.5+1.6+72.9+0.9+13.6+72.3 thousand). Communication services (29.5 thousand) employs 15.5 percent of this total.

23 These percentages were calculated as follows. Total non-manufacturing R&D from Table 2-1 is $31,321 million ($5,491+$339+$10,092+$132+$2,084+$13,183 million). Computer related services ($10,092 million) is 32.2 percent of this total. Similarly, the total number of scientists and engineers employed in non-manufacturing is 190.8 thousand (29.5+1.6+72.9+0.9+13.6+72.3 thousand). Computer related services (72.9 thousand) employs 38.2 percent of this total.

24 The Census of Service Industries (U.S. Department of Commerce 1995a) shows that SIC 737 and 871 represent 10.9 percent of the receipts for the "other private services" listed in Table 2-1, while "other private services" make up 37.5 percent of the private services for the service sector as a whole. Employment figures from the Census show that SIC 737 and 871 represent 6.2 percent of the employment in "other private services" which itself takes 44.9 percent of the employment in private services.

25 We believe that the technology development activities of most service sector firms are best categorized as belonging to the T&E portion of the RDT&E spectrum. To the extent that patents reflect the whole cycle of development and implementation of firms' innovative activities, and not just the inventive activities reflected in R&D data, as suggested by

Table 2-1. Total R&D Activity in Selected Industries

Industry and SIC Code	1993 Total R&D* ($millions)	1993 R&D Scientists and Engineers (thousands)
Total	$118,334	764.3
Manufacturing (SICs 13,20-39)	$87,013	573.5
Communication services (SIC 48)	$5,491	29.5
Electric, gas, and sanitary services (SIC 49)	$339	1.6
Computer programming, data processing, other computer-related engineering, architectural, and surveying services (SICs 737,871)	$10,092	72.9
Hospitals and medical and dental laboratories (SICs 806-07)	$132	0.9
Research, development, and testing services (SIC 873)	$2,084	13.6
Other non-manufacturing industries**	$13,183	72.3

* These estimates are total R&D performed in each industry, including private, Federal, and other sources of funding.

** Other non-manufacturing industries include agricultural services, forestry, fishing, and hunting (SICs 07-09); mining (SICs 10, 12-14); construction (SICs 15-17); transportation, communications, electric, gas, and sanitary services (SICs 40-42, 44-49); wholesale and retail trade (SICs 50-59); finance, insurance, and real estate (SICs 60-65); holding and other investment offices (SIC 67); hotels and motels (SIC 701); business services (SIC 73, except 737); automotive repair, service, and parking and miscellaneous repair services (SICs 75-76); motion pictures and amusement and recreation services (SIC 78-79); health and legal services (SICs 80-81, except 806-07); social services (SIC 83); museum, art galleries, botanical and zoological gardens (SIC 84); engineering, accounting, research, management, and related services (SIC 87, except 871 and 873); and miscellaneous services (SIC 89).

Source: National Science Foundation (1996).

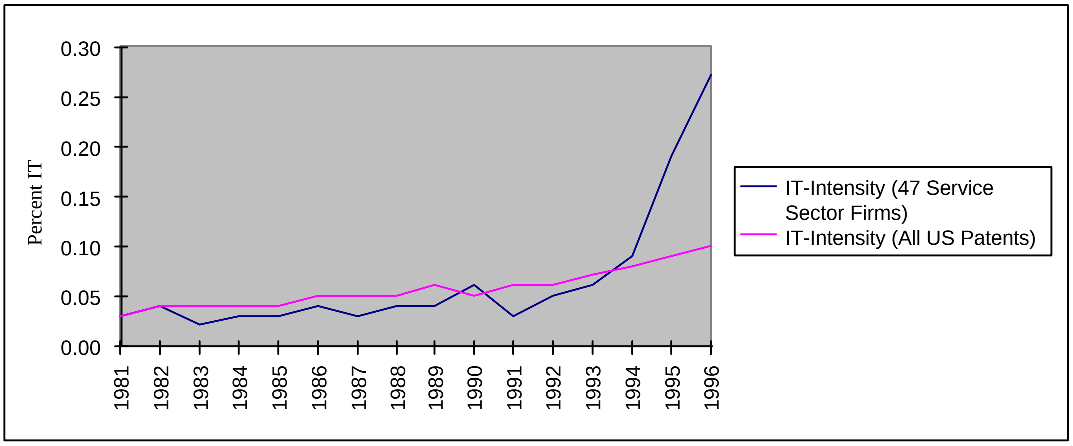
Figure 2-1 indicates that the patenting activity of selected service sector firms is increasingly IT-related.[26] The percentage of IT technologies in the patent portfolios of service sector firms remained relatively flat at less that 5 percent throughout the 1980s. However, that percentage grew noticeably during the early- and mid-1990s. Currently, it is over 25 percent. This upswing in a relatively narrowly defined

Pavitt (1985), patent data may capture more relevant technology activity for service sector firms than R&D data alone. (This positive aspect of using patent data to analyze service sector behavior has to be balanced against the general understanding that the service sector's propensity to patent is low.)

26 The results presented in Figure 2-1 are for 47 service sector firms in the MIT database with significant patenting activity. This database is discussed in Chapter 4. A patent is said to be IT-related if it is classified (in whole or in part) in any of three International Patent Classification codes (Computing, Calculating, Counting; Information Storage; or Transmission of Digital Information).

technology area (as defined, IT-related international patent categories comprise just 3 of one hundred or so patent categories) is probably indicative of a more significant shift to IT-related technology than the percentage indicates. Looking at all U.S. patent activity — manufacturing and non-manufacturing — IT intensity has risen from 2-3 percent to 9-10 percent over the period 1981-1996. Based on these data, the service sector firms represented in Figure 2-1, and perhaps service sector firms in general, are especially IT intensive.

Figure 2-1. Growth of IT Intensity: Selected Service Sector Firms vs. All Patent Holders



Source: CHI Research, Inc., 1996b

2.3 TECHNOLOGY FLOWS INTO SERVICE INDUSTRIES

2.3.1 An Estimate of "Imported" Information Technology

The central importance of IT to the service sector comes even more sharply into view when we consider the IT embodied in equipment purchased from outside the sector. IT is the technology that has brought about the most pervasive and dramatic changes in the growth of the service sector. As Quinn et al. (1994, pp. 1-2) notes:

> As IT becomes less expensive, more portable, better integrated and interconnected, and embedded in [an even] wider variety of devices, new applications in [the fields of transportation, financial services, banking, insurance, retail and wholesale trade, telecommunications, health care, and professional and personal services] and whole new industries ó such as interactive multimedia systems for business, home entertainment, and communications purposes ó are likely to evolve and to have profound effects on industry structures, employment, and economic growth. Moreover, the U.S. economy revolves increasingly around various important white-collar service industries (e.g., research, design, financing, education, accounting, marketing, logistics planning, communications,

and information management) rather than blue-collar shop floor production. These activities are central to the individual service industries and are critical in producing value within manufacturing and other goods-producing companies. The effectiveness with which IT is deployed in services thus strongly influences U.S. standards of living and competitiveness in world trade.

Table 2-2 contains the data needed for a benchmark estimate of imported technology (i.e., technology flows into) versus indigenous technology (i.e., RDT&E-based) in service industries. The implicit assumption underlying the analysis that follows is that information technology purchased by companies in the service and non-manufacturing industries is a lower-bound estimate of the total technology that is imported into those industries. Certainly, companies in service industries purchase other capital equipment that has embodied in it non-information technology and, as pointed out at the beginning of this chapter, there are many external sources of technology available to firms.

Table 2-2. Comparison of Value Added, Information Technology Investments, and Company Performed R&D: 1991

(in $ billions)

INDUSTRY	Value Added	IT Investments	R&D
Non-Services	$1,178.7	$26.7	
Agriculture, forestry, and fisheries	$90.9	$0.0	
Mining	$36.7	$0.9	
Construction	$210.1	$0.5	
Manufacturing	$841.0	$25.3	$67.6
Services	$3,391.2		
Private	$2,691.8	$126.8	
Transportation	$140.8	$3.8	
Communications	$95.3	$21.1	
Electric, gas, and sanitary services	$99.0	$8.0	
Wholesale trade	$266.0	$17.0	
Retail trade	$403.3	$17.9	
Finance, insurance, and real estate	$685.0	$38.7	
Other private services*	$1,002.4	$20.3	
Government	$699.4	$45.0	
Private Non-Manufacturing	$3,029.5	$128.2	$22.9

* Includes hotels; personal services; business services; auto repair; services, and parking; miscellaneous repair services; motion pictures; amusement and recreation services; health services; legal services; educational services; social services; membership organizations; museums, botanical, zoological gardens; engineering and management services; private households; and services not elsewhere classified.

Source: Quinn et al. (1994) and National Science Foundation (1996).

The data in Table 2-2, albeit conservative in terms of its characterization of imported technology into the service sector, show that 82.6 percent of 1991 investments in IT hardware was by private service sector industries.[27] Included in these estimates of information technology investments are expenditures for office, computing, and accounting equipment; communications equipment; instruments; and photocopy and related equipment.

2.3.2 Making Information Technology Work

While imported information technology into the service sector is approximately 83 percent, information technology requires significant adaptation costs that may not have characterized imported technologies in the past. In fact, there is reason to believe that these costs of adapting and implementing information technology exceed the costs of the imported hardware that embodies the R&D of its developers.[28] Including the service sector's expenditures for implementation of information technology in its technology bill *reverses* the notion that the preponderance of service sector IT is purchased.

The International Data Corporation (IDC) provides a breakdown of the various costs of using information technology for basic types of information technology sites.[29] For small centralized sites, there is the cost of the operation staff (54 percent), applications development staff (20 percent), software (12 percent), hardware (9 percent), and support (5 percent). For large distributed sites, IDC reports that there is the cost of the operations staff (38 percent), the central site location (17 percent), software (25 percent), hardware (17 percent), and support (5 percent).

Based on these estimates, if a representative service sector company spends $100.00 on technology, $83.00 of which is for imported information technology hardware, and if that $83.00 represents 17 percent of its total cost to make the information technology operable, then the total cost for using the information technology is $488.00. As has been observed:[30]

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27 This percentage equals ($126.8/(126.8+$0.9+$0.5+$25.3)), or total private service sector investment divided by the sum of total private service sector IT investment and total non-service sector IT investments.

28 International Data Corporation (1996) provides the recent statistics demonstrating that implementation costs exceed the hardware costs. Greenwald et al. (1994) emphasize the investments that companies must make above and beyond the cost of IT hardware in order to ensure the productivity of information technology.

29 See International Data Corporation (1996).

30 See International Data Corporation (1996).

> [W]e are heading for a wired workplace, a wired marketplace, even a wired society. However, there is a price to be paid for all this connectivity. The nearly universal implementation of client-server systems requires living with new levels of complexity and new hardware and software that people must be trained to use. Moreover, highly skilled personnel must be hired to install, manage, maintain, and administer these far-flung networks. The result is that staffing costs have become the largest contributor to total networked computing costs, regardless of the size of the installation.

Many of these costs come about because of market barriers and frictions related to the effective identification, transfer, and assimilation of information technology. The scale of these barriers and their nature is the subject of Chapters 4 through 8.

2.4 THE STRATEGIC INTENT OF IT PURCHASES

The preceding analysis leads us to conclude that approximately 83 percent of the technology purchased by service industry firms is information technology. And, the cost to service industry firms to adapt and implement this technology is often greater than the initial hardware technology by a factor of five. In an effort to gain greater insight into the service sector's strategic reasons for purchasing IT, specific questions were added to the 1996 *InformationWeek* survey of the 500 largest domestic users of IT.[31] The questions posed in the survey are presented in Table 2-3.

Our goals for this survey were (1) to better understand the strategic importance of information technology in major corporate enterprises, and (2) to gain insight into factors that are important to firms when they purchase new information technologies or information systems. Understanding the strategic importance of how the technology is used is an important step in identifying barriers to their wider use.

2.4.1 The Strategic Importance of IT to Service Sector Firms

Table 2-4 shows the responses from service sector firms to the first question (why your organization invests in information technology). The mean response was greater than 5.5 (the median value on a response scale of 1 to 10) for eight of the 10 choices indicating that service sector IT executives attached a relatively high

[31] See Brynjolfsson and Hitt (1996a). *InformationWeek* expressed interest in conducting a broad-based survey of IT users and contacted Brynjolfsson and Hitt to design the survey instrument. Two questions were added to the survey to gather specific information for this study (see Table 2-3). Of the 500 surveys administered by *InformationWeek*, 189 were returned. Of these, 103 were from service sector firms; however, not all of these 103 firms responded to both questions.

importance to many factors. However, customer satisfaction was the dominant response, followed by timeliness, product quality, and reduced costs.[32]

Table 2-3. *InformationWeek* Survey Questions

Question 1: Please rate the importance of each of the following as reasons as to why your organization invests in information technology. *(Please rate each on a scale of 1 to 10, where 10 = Extremely Important and 1 = Not At All Important.)* Improve customer service Improve flexibility (e.g., customization) Improve managerial information systems Improve timeliness (e.g., faster time to market) Improve product quality Learn about new technologies Maintain state-of-the-art IS shop Provide IT infrastructure Reduce costs Support reengineering or business process redesign
Question 2: Please rate the importance of each of the following factors in guiding your organization's selection of new information technologies/systems. *(Please rate each on a scale of 1 to 10, where 10 = Extremely Important and 1 = Not At All Important.)* Adherence to open (non-proprietary) standards Availability of service and support Compatibility with existing systems Functionality Low initial cost Low training costs System reliability

2.4.2 New Information Technology Performance

Table 2-5 reports the responses from service sector firms to the second question (IT factors that guide purchasing decisions). Again, respondents attached a great deal of importance to all the options (all had a mean response greater than 5.5). However, the dominant factor is system reliability.[33]

32 Separate correlations were calculated for measures of firm size (sales and net income) and the mean responses shown in Table 2-4. With the exception of the response category “reduce cost,” which is correlated positively with firm size (at a .01 level of significance), firm size is unrelated to response scores.

33 Separate correlations were calculated for measures of firm size (sales and net income) and the mean response shown in table 2-5. Uniformly, firm size is unrelated to the response scores.

Table 2-4. Service Sector Firms' Responses to Survey Question 1

Please rate the importance of each of the following as reasons as to why your organization invests in information technology. *(Please rate each on a scale of 1 to 10, where 10 = Extremely Important and 1 = Not At All Important.)*

Response Category	Mean
Improve customer service (n=99)	9.52
Improve timeliness (e.g., faster time to market) (n=99)	8.84
Improve product quality (n=98)	8.57
Reduce costs (n=99)	8.52
Improve flexibility (e.g., customization) (n=99)	8.36
Improve managerial information systems (n=99)	8.06
Support reengineering or business process redesign (n=97)	8.00
Provide IT infrastructure (n=97)	7.48
Learn about new technologies (n=98)	5.37
Maintain state-of-the-art IS shop (n=98)	5.28

Table 2-5. Service Sector Firms' Responses to Survey Question 2

Please rate the importance of each of the following factors in guiding your organization's selection of new information technologies/systems. *(Please rate each on a scale of 1 to 10, where 10 = Extremely Important and 1 = Not At All Important.)*

Response Category	Mean
System reliability (n=98)	9.42
Functionality (n=99)	9.16
Availability of service and support (n=98)	8.99
Adherence to open (non-proprietary) standards (n=99)	8.30
Compatibility with existing systems (n=99)	7.91
Low initial cost (n=99)	6.48
Low training costs (n=99)	6.34

2.5 CONCLUSIONS

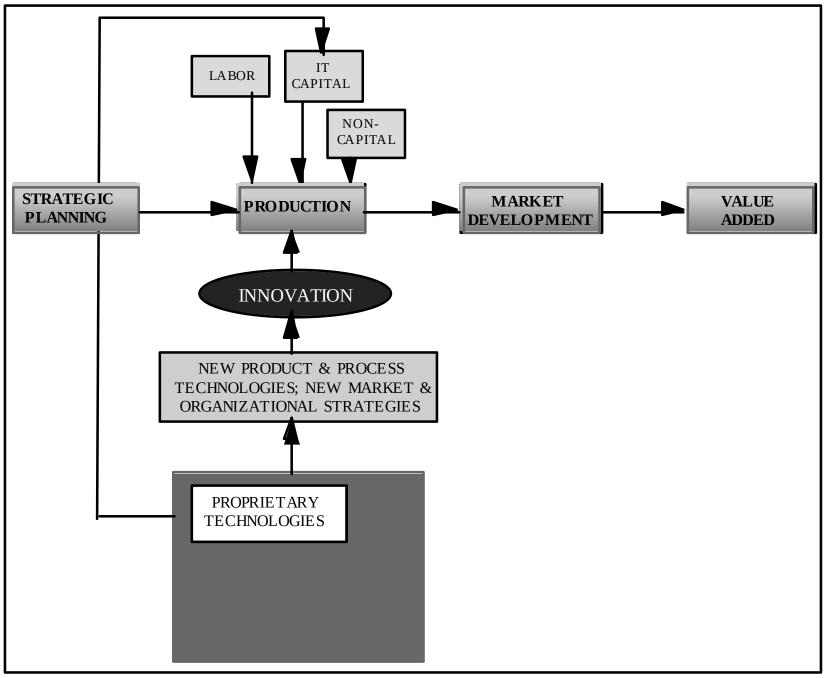
The manufacturing sector still performs the lion's share of R&D, but the service sector now develops more technology than it did two decades ago. Indeed, the growth in service sector R&D has been quite dramatic. Service sector R&D is dominated by the communication services and computer services industries. Together they account for almost 50 percent of all service sector R&D. Systematic analysis of the trade press, R&D expenditure data, and patent data all confirm the centrality of IT to service sector development. The importance of IT to the service sector suggests that it makes sense to consider this broad technology as a focal point for the development of an initial technology policy in support of the U.S. service sector.

Over and above the importance of IT in the internal innovation process of the service firms, these firms acquire far more technology embodied in purchased capital equipment. But significantly, the full cost of implementing IT is more than four times as great as IT purchase costs. These high implementation costs suggest the presence of significant barriers to IT implementation. A survey of service sector technology managers indicates that firms are driven to invest in IT as a means of improving customer satisfaction and that IT system reliability is the most effective way to achieve customer satisfaction through IT.

Reflecting some of these findings, Figure 2-2 modifies the technology-based economic growth model to reflect the importance of IT to the service sector "production function" and to improving service sector performance (value added) in the market place.

The following chapters will estimate the scale of the barriers that prevent service sector firms from procuring more IT in efforts to improve their quality: cost performance; to determine the nature of the barriers that cause underinvestment in IT; and to determine the appropriate policy response by NIST.

Figure 2-2. The Role of Embodied IT in Service Sector Growth.[34]



[34] According to information obtained in the case studies presented in Chapters 5-8, proprietary technologies for service firms include a large measure of test and evaluation activity. To the extent that these test and evaluation activities are standandardized or shared, infratechnologies would also come into play at this point.

3. THE CONCEPT OF MARKET FAILURE AND ITS APPLICATION

3.1 INTRODUCTION AND OVERVIEW

This chapter explains the concept of market failures and presents examples of various causes of market failures from the literature concerning the development and use of technology in the service sector. It is important to fully explore the concept of market failures and the related concepts of "barriers to investment" and "underinvestment." They will be essential to our detailed case study investigations in later chapters of this report.

After a brief overview of the relationship of these concepts and their policy relevance, we proceed to a detailed discussion and explanation of the various barriers to technology and the associated market failures. This is followed by a brief discussion of the appropriate policy response to broad categories of barriers to technology. (Readers familiar with the various barriers to technology and the appropriate policy instruments are advised to turn to the presentations of the various types of evidence of market failure presented in the following chapters. Chapter 4 presents firm-level statistical evidence of the degree of market failure in the service sector. Chapters 5 through 8 present case studies that explore the market failure implications of technological developments in each of three industries.)

3.1.1 Overview of Market Failures

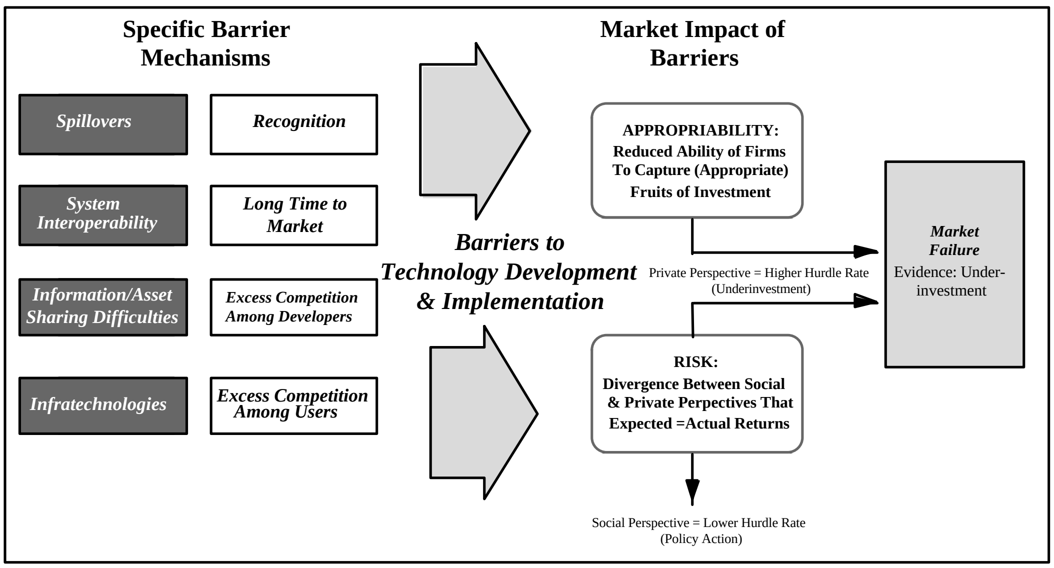
Because the existence of market failures is the chief economic rationale for government involvement in technology development activities, it is important to understand this concept. Equally important, the policy instruments available to policy makers must be matched to the specific type of technology barrier to have the desired effect. (Tassey 1995, 1997)

We will discuss eight types of barriers and their impact on firm's expectations regarding their ability to capture the fruits of their investments ("appropriability") or realizing planned returns (risk). These barriers, and the underinvestments they can cause, are best addressed by specific technology policy instruments. The policy instruments available to NIST for mitigating barriers to technology investment include support for generic technology development (through the Advanced Technology Program) and the development of "infratechnologies" for measuring compliance with voluntary standards or standard methods.

These distinctions will be very important for the discussions of case study evidence and for the policy discussion that concludes the report. Before proceeding with a review of the various barriers to technology, and the associated market failures, it is important to understand the broader relationships among barriers, underinvestment, and market failures. This relationship is depicted in Figure 3-1.

There are two general causes of market failure: 1) risk and uncertainty or 2) difficulties capturing (appropriating) the returns from an investment. These basic difficulties manifest themselves in various barriers to technology that result in the failure of market place incentives to induce the level of investment that would likely take place if those barriers did not exist.

Figure 3-1. Barriers, Market Failures, and Underinvestment



A company's overall exposure to risk from a particular technology investment project will depend on the collection of projects in the company's portfolio. A large firm with a diversified portfolio of investment projects might find a particular project less risky than a small firm. Similarly, from a social or government policy point of view, society may perceive less risk than an individual firm, large or small, and technology policy is implemented from a social point of view to induce a higher level of technology investment.

Barriers to technology cause essentially two types of market failure in service industries. First, barriers are likely to cause underinvestment for new technology.[35] Second, barriers can prevent the full and efficient use of available technology. Facing barriers, private firms find that the costs of additional investment exceed the anticipated benefits. The private sector will find the additional investments unprofitable, because those investments are risky and the returns are difficult to appropriate (capture). If barriers to technology were reduced, causing higher appropriation of returns and lower risk, the private value of additional investment would more closely approach its social value. Thus, reducing barriers to technology would stimulate additional desirable investment.

3.1.2 Sources of Market Failure: Discussion and Examples of Barriers to Technology

This section describes specific examples of barriers to technology acquisition, development and use that should be of special concern for the service sector.[36] Here, following brief definitions of appropriability and risk and building upon Tassey (1995), we define and illustrate the prominent barriers to technology and the associated market failure. By relating the types of barriers to situations involving the development or use of technology in the services sector, it is hoped that the meaning and import of these barriers will become clearer to the reader.

Appropriation of returns. If a company cannot realize all of the returns from an investment, because some returns leak to other firms in the form of knowledge and ideas, and to consumers who would be willing to pay higher prices than the market charges, appropriability difficulties result in a level of investment that is less than optimal from society's standpoint.

Risk. Risk is a measure of the extent to which actual outcomes may deviate from the expected outcomes. More precisely, risk is the estimated probability of return on investment falling below the minimum acceptable hurdle rate. The end results of technology development may be very poor or perhaps considerably better than the expected outcome. Thus, a firm is concerned about the risk that its investment

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35 "Investment" is interpreted in the broad sense, encompassing investment for new IT hardware, embodying imported R&D, and investment originating in the service sector and pointed at developing, testing and implementing new technology.

36 Overviews of the barriers from the perspectives of the managerial literature, the industrial organization economics literature, and the public policy and technology literatures can be found respectively in Teece (1980), Baldwin and Scott (1987), Tassey (1995). These sources review the barriers to both the creation of technology by R&D investment and the transfer of technology from its creators to others who apply it.

will fail technically, or even if technically successful, that the investment may not be profitable.[37] When private companies either cannot accurately estimate risk or risk becomes excessive along absolute or time dimensions, the decision-makers will use higher discount rates than the public would apply.[38] From society's standpoint, the market would fail to provide enough investment.

Risk and appropriability difficulties are often confounded in the problems causing a barrier to technology. Some project circumstances will both shift the probability distribution for project outcomes—changing its expected value—and change the aspects of the distribution that affect the project's risk. With an understanding of what is meant by appropriability difficulties and risk, we turn to examples of barriers and the associated underinvestment in IT.

Spillovers. Returns from one firm's investment in technology may spill over to other firms. A firm decides how much to invest based on its assessment of private benefits, which does not capture those spillovers. Society would prefer more investment, which would occur if the firm based its decisions on a higher marginal benefit schedule that captures all returns—in the form of knowledge and ideas—to that investment. According to Tassey (1995, p. 43), spillovers are likely to result when "the nature of the technology…is such that the assignment of intellectual property rights is difficult." Also, Tassey (1995, p. 44) observes that appropriability will be difficult, and underinvestment may result, when the buyers of technology can bargain for lower prices or if imitators successfully compete with the innovator.[39]

Spillovers of knowledge are typically pervasive whenever technology is being developed and applied; services are no exception. The most prominent example is undoubtedly the concern about appropriability of returns to the production of knowledge made available on the Internet. Phillips (1995) discusses the potential for publishing on the Internet, and the major problems to be dealt with such as concerns about copyrights and the proprietary nature of information.

Transaction Costs: Information-Sharing and Asset-Sharing Difficulties. Teece (1980) explains the implications of the paradox of information and opportunistic behavior by firms attempting to share the

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37 Often the term "uncertainty" is applied when knowledge is insufficient to form a probability distribution of returns.

38 A firm's decision-makers will likely perceive the risk of investment differently than would society. From society's perspective, the risk from the pooled collection of investments typically implies lower discount rates.

39 See Baldwin and Scott (1987) for a complete set of references and discussion of these appropriability difficulties.

information and facilities needed for the exchange and development of technology. The paradox of information is that without telling a potential customer about the technological and managerial know-how a seller of technology believes will be productive for the customer, the customer cannot value the information and hence is unlikely to pay an appropriate amount for it. Yet, if the seller reveals the information, the buyer will have it and won't need to pay for it. Patent laws and legal contracts surmount some of these problems, but patent laws provide imperfect protection and contracts can be expensive, unwieldy, and ineffective. Such information sharing problems reduce investment by making it more difficult to realize the full benefits of the investments. These information-sharing difficulties can necessitate internal financing of R&D and other investments in technology because the paradox of information will inhibit full disclosure of information to creditors and other outside investors, thus increasing the cost of outside investment funds. As a result, very capital intensive investment projects (Tassey, 1995, p. v) may take a prohibitively large portion of the investment budget, and again, worthwhile investments may be lost.

As Teece (1980) explains, the successful transfer of technology from one firm to another requires careful teamwork with active interaction between the seller and the buyer of the technology. In such circumstances, both the seller and the buyer are exposed to hazards of opportunism. For example, sellers may fear that buyers will capture the know-how too cheaply or use it in unexpected ways to become a competitive threat. Buyers may worry that the sellers will fail to provide the necessary support to make the technology work in the new environment, or that after learning about the buyer's operations in sufficient detail to transfer the technology successfully, the seller would back away from the transfer and instead enter the buyer's industry as a technologically superior competitor.

Teece (1980) emphasizes that when the barriers to technology development and acquisition become too severe to be handled by arms-length transactions in the market or by detailed contracts specifying the obligations of the buyer and the seller of the technology, the selling and buying organizations will merge, or the seller or the buyer will expand internally and acquire a new line of business to allow the interactive sharing across activities to take place within a single firm (thereby avoiding the hazards of opportunistic behavior and the transaction costs of dealing in markets or with contracts). One suspects that the recent movement (Wolfe 1995) of manufacturing firms into the service industries is caused by the need to transfer technology from its originators to the service industries. That shift fits well with Brian Quinn's (1992) observation that manufacturing firms are increasingly devoting much of their activities to the provision of services. Barriers to technology transfer dictate that an intrafirm solution to the sharing of technological and managerial know-how will improve performance over what would occur if the sharing were done at arms length in the market or with contracts between independent firms.

Tassey (1995, p. 43) emphasizes the barrier to technology that results when "the complexity of the technology makes agreement with respect to product performance between buyer and seller costly." Sharing R&D and technology may be especially difficult when (Tassey, 1995, p. 42) "the evolving nature of markets requires investment in combinations of technologies that, if they exist, reside in different industries that are not integrated." Tassey observes (1995, p. v) that "technical risk, especially in the early phases of development can become prohibitive because . . . . requirements for conducting R&D . . . demand multidisciplinary research teams, unique research facilities not generally available within individual companies, or "fusing" technologies from heretofore separate, non-interacting industries. Investment in the early (generic) phases of many emerging technologies is adversely affected by such conditions." Tassey goes on to observe (1995, p. v) that "High technical risk can translate into high market risk when the required R&D is capital-intensive, so that the minimum cost of conducting the research is high relative to a firm's overall R&D budget." As Teece explains (1980), the possibilities for opportunistic behavior in "thin" markets may make it impossible at reasonable cost for independent firms to share the capital assets even if there were no R&D-information sharing difficulties to compound the problems.

Although the use of IT is growing in the magazine industry, Wilson (1995) reports that only 11 percent of editors and 6 percent of reporters have CD-ROM drives; 50 percent of art departments still require submissions as photos or slides. Some publishers have successfully deployed the new IT and could presumably sell their expertise to other publishers. However, the hazards of opportunistic behavior may prevent that—the publisher with IT sophistication could pirate the authors of the publisher paying for its consulting services. An intra-firm solution effected via merger could transfer the knowledge without such risk; thus, one reason for mergers among publishers would be to share knowledge about the successful use of IT.

Recognition. Firms may fail to appropriate social returns because they do not recognize potential applications of their technology. Tassey (1995, p. 42) emphasizes the case where "the scope of potential markets is broader than the scope of existing market strategies, so that individual firms do not project economic benefits from all potential market applications of the technology".

The returns from innovation cannot be appropriated if innovators do not recognize the opportunities. In part for that reason, Meltzer (1993) reports that a workshop of concerned practitioners from industry, academia, and government who addressed ways to improve the assimilation and productivity of information technology concluded that collaborative R&D to develop appropriate IT products, services, and environments is a key to good performance. Baldwin and Scott (1987) review articles hypothesizing that diversified firms will have good R&D performance because of their ability to recognize applications of knowledge in the different environments with which they are involved. Collaboration can achieve such benefits of diversification.

Long Time to Market. As discussed above, private decision-makers may perceive more risk in their investments than the public does, and therefore discount the value of returns at a higher rate than would the public. The lag between an initial investment and its returns, through the discount rate, reduces the present value of those expected returns. (Tassey 1995, p. 41).

Investments in IT are often risky, with payouts uncertain and coming long after the initial investment. Kim (1995) notes that by committing the company to a hybrid fiber/coaxial (HFC) architecture as the approach for delivering all residential IT services over a single pipe, Pacific Bell faces the risk that a different residential broad-band architecture will win the day. As a whole, society can be happy with the winning solution to the residential broadband architecture, but individual companies will win or lose depending on how their choices fare. Pacific Bell has taken steps to mitigate the risk, however. It has paid attention to the scalability of its investments in HFC.

With IT, there is the need to wait for aspects of the system that uses the new technology to be in place. Although satellite television broadcasters know that new channels will soon be digital, broadcasting companies are worried about the risks involved in launching digital services, so they wait and even launch new packages of channels using analog TV (New Media Markets 1995).

Interoperability of Systems. The costs of adoption and use of new technology are dramatically lower for independent users who successfully coordinate the standards and hence the compatibility of their technologies. Individual firms pursuing their own self-interests in a market setting with uncertainties about the evolution of technologies are unlikely to succeed in coordinating a network. For just one empirical example, Brynjolfsson and Kemerer (1994) conclude that "[b]ecause of network externalities, the success of a software product may depend on the creation of, or conformance to, industry standards, in addition to the value of its intrinsic features."

Tassey (1995, p. vi) observes that

> "Most technology-based products in today's complex market place are part of larger *systems* of products (examples are an automated factory and a communications network). Under such industry structures, if a firm is contemplating investing in the development of a new product but perceives a risk that the product—even if successful technically—will not "fit" or "interface" with other products in the system, the additional cost of attaining *compatibility* or *interoperability* may reduce the expected [rate of return] to the point that the project is not undertaken. Similarly, multiple sub-markets may evolve, each with its own interface requirements, thereby preventing economies of scale or network externalities from being realized."

With IT, compatibility or interoperability problems are pervasive. For example, the growth of wireless communications requires cellular carriers to arrange interoperability of their systems. Wetli (September 1, 1995) reports that GTE and Ameritech announced an interoperability arrangement which would allow their customers to maintain service while traveling between the two carriers' coverage areas. Wetli (February 15, 1995) provides an example of the uncertainties for new technologies that require standards in order to work within a network. The new analog display services interface (ADSI) standard is a communications protocol developed by Bellcore. The development standardizes products and services in networks with screen phones. ADSI services have been slow to develop as providers wait for customers to buy the screen phones, but of course the customers haven't been buying the phones since there are not many ADSI services available.

Excessive Competition Among Technology Developers. If competition in the development of new technology is very intense, each firm, knowing that the probability of being the successful innovator is low, may project that its returns will not be sufficient to cover costs. Further, even if the firm innovates, it can still face intense competition in application because of competing substitute goods, whether patented or not. Especially when the costs of imitation are low, firms will not anticipate sufficient returns to cover the R&D investment costs.

However, despite the concern about excessive competition, when considered separately from the other barriers (interoperability problems for example could be compounded when there are many sources of technology development), competition appears to be spurring technology development rather than retarding it. For a prominent example, providers of local and long distance telephone service, cable TV, and broadcast satellite providers are all competing to provide the bandwidth that customers want at a reasonable price (Stuck 1995). However, there are types of technology development—such as nonproprietary infratechnology—where competition may be a barrier to technology.

Nonproprietary Infratechnology. Tassey (1995, p. 45) illustrates the foregoing idea that competition can be too intense by discussing the market risk and appropriability problems associated with the decision to develop a test method that will be a part of an industry's nonproprietary infratechnology. Tassey (1995, p. vi) observes that infratechnology—those elements (often provided by the federal laboratories) of an industry's technology that must be shared among the industry's firms to support the industry's performance (e.g., a test method)—must be widely available to buyers and sellers in order to have a significant economic impact:

> "The *nonproprietary* or *public good* character of such infrastructure (resulting from common use) leads to underinvestment by individual firms because insufficient benefits are captured. This *capturability* or *externality* problem is accentuated by the prospect that, if several companies develop alternative infratechnologies (different approaches to performing the same test), only one version or a hybrid of several versions is eventually accepted as the industry standard. Investments in the other versions have to be written off."

Thus, an early test-method innovation may be supplanted if an alternative method is selected as the industry standard. Privately anticipated benefits may not exceed the costs; from a social point of view, the result may be an underinvestment in infratechnology. Further, competition in the development of infratechnology can result in several competing test methods. In such cases, the market will generate confusion and additional product assessment costs by potential buyers. These 'transaction costs' add to the overall cost of the new product and slow its market penetration. (Tassey, 1995, p. 44)

IT development and commercialization can be inhibited in part because the necessary infratechnology is nonproprietary. For example, Haber (1995) reports that the purchasers of asynchronous transfer mode (ATM) services will face difficulties because of evolving standards and limited functionality and services. As Terzian (1995) explains, the newness of ATM has meant that carriers and end users must frequently pioneer the evaluation of the technology. Development of the testing involved is the sort of infratechnology that markets may not provide very well.

Excessive competition among technology implementers. In order to adopt new technology, service firms must invest in organizational changes, training, and software as well as in new information technology hardware. It may be difficult to recover the costs of such investments when technology is changing rapidly. Prices of services tend to be low because of the competition in service industries, and the overhead costs of maintaining cutting-edge information technology may result in costs that exceed unit prices in highly competitive dynamic environments. The shortfall of price is especially likely for the first firms to adopt a new technology if imitators are able to observe those innovators and thereby reduce their overhead costs for adopting the new technology. Because it is difficult to secure sufficient returns to cover the costs of introducing the new technology, firms will underinvest in the deployment of the already available technologies.

Despite these concerns, competition in technology acquisition and use appears to be promoting good performance from a social standpoint, if not from the standpoint of some individual competitors. Describing the banking industry, Llewellyn (1995) reports both the immense pressure of increased competition and the developments in technology that are changing the ways that financial services are delivered. Holland et al. (1994) actually argue that the competitiveness of banking in the United States has caused U.S. banks to be more innovative in their uses of IT. Schwarzwalder (1994) reports that the database industry shows increasing competition among data banks, yet the result has been an increase in the scope of existing services and new products and better choice of access for the corporate and academic customers of on-line information services. According to Caldwell (1994), the new IT is generating a burst of productivity on Wall Street. Competition in the use of the new IT is keen, and that competition has caused firms to deploy technologies to cut costs and increase speed and flexibility.

3.2 TECHNICAL PERFORMANCE: A USER PERSPECTIVE ON TECHNOLOGY BARRIERS

Insight into the sources of market failure can also be gained by assessing today’s IT applications against IT performance criteria considered ideal by technical experts. In other words, we might ask of today’s IT implementations, “Why is this IT implementation not operating as it should or as you would like it to behave?” or, to put it another way, “What are the technological barriers to IT implementation?” Information technology experts (Perine et al., 1996) regard the following five performance attributes as essential to effective IT systems implementation:

- *Usability* (easy to learn and remember, productivity enhancing, error resistant, and friendly).

- *Interoperability* (two or more systems are able to interact with one another and exchange data according to a prescribed method in order to achieve predictable results).

- *Scalability* (the system can be made to have more (or less) computational power by configuring it with a larger (or smaller) number of processors, amount of memory, interconnection bandwidth, input/output bandwidth, and amount of mass storage).

- *Reliability* (the system can be counted upon to perform as expected).

- *Security* (the ability of organizations and individuals to use information technology with the assurance and trust that the confidentiality, integrity, reliability, and availability of information resources are protected).

Accordingly, we draw examples from the literature representing these key attributes and illustrate the pervasiveness of the IT implementation barriers in shaping the evolution of new IT technology across the service sector. As we demonstrate below, each of these five IT performance attributes is important to both suppliers and users of IT. While only selected examples are provided below, these were drawn from an extensive review of hundreds of trade press articles and case studies extracted from a broad literature review. Analysis of this literature suggests the persuasiveness of barriers to the realization of satisfactory IT performance, across the 5 attributes and across the scores of industries that comprise the service sector.

Usability: Users of a technology must find the technology accessible, useful, and reasonably easy to use. For example, Kirchner (1995) emphasizes that communications from personal computers are too complicated. Transactions such as sending electronic mail or linking with the World Wide Web have become less difficult recently, but users still cannot take these services for granted. Churbuck (1995) reports that computer retailers face a staggering number of calls from users of computers needing assistance. He reports that there is simply not enough profit in a commodity PC or in a CD-ROM to pay for all of the assistance that unsophisticated customers need. Thus, technology and marketing are on a collision course. The users of personal computers are demanding more sophisticated equipment, but the new technologies have gone beyond the technical competence of typical users.

Scalability: Information technology is changing so rapidly that successful and efficient users must be flexible and able to let their capabilities evolve with the changes in information technology without the need for completely replacing existing technology with each new development. Thus, an information technology environment must be scalable if the purchasers of the technology are to have the confidence to invest in technology that will surely need to be upgraded regularly as IT evolves. For example, Wilken (1995) reports that the provision of Switched Multi-megabit Data Services (SMDS) technology to the printing industry by the regional Bell operating companies provides the scalability that printing firms need to support the future applications because SMDS can be integrated with existing frame relay and Integrated

Service Digital Network (ISDN) technologies plus with the emerging technologies such as asynchronous transfer mode (ATM). Thus, with SMDS technology Denigris (1994) observes that a telecommunications company can help the users of its services plan to avoid the rapid obsolescence of systems purchased today.

Interoperability: Information technology must be interoperable to function in networks. The growth in size and importance of networks increases this challenge. For example, Means (1995) observes that the interactive broadband operations support systems (OSS) to manage billings for the proliferation of products offered by cable and telephone companies will have to inter-operate with other network components such as network management systems, various types of set-top boxes, and various types of video and other database servers.

Reliability: The productivity of the information technology requires reliable equipment and networks. For example, Terzian (1995) explains that the newness of asynchronous transfer mode (ATM) technology requires that carriers and end-users pioneer the evaluation, installation, tune-up, and maintenance of equipment. Each of these phases of ATM technology deployment requires specific testing to meet requirements and to ensure success. Terzian describes several such tests — cell address verification, ATM bit error rate tests, and traffic congestion tests — that service providers must use to determine whether the quality levels specified in their contracts with customers are met and how the reliability problems caused by traffic congestion can be treated with the tests described.

In other examples of the requirement for reliability, Levitt (1995) reports that integrated services digital network (ISDN) is worth the additional cost relative to older telephone service because, among other things, it is more reliable, and Rimmler (1995) discusses the need for new capabilities for testing to support the functionality, reliability, and performance of a mature telecommunications network with advanced-intelligence network services.

Security: The complete use of information technology's potential and its successful use requires security in an information exchange. For example, Phillips (1995), in the context of a discussion of on-line publishing, emphasizes major problems of authorship, copyright, confidentiality, privacy, and the proprietary nature of information when placing it on publicly accessible computers. In another example, Calem (1995) describes the large technological investment (in a neural net computer system that detects patterns) being made by Visa International in order to develop effective monitoring of credit card activity to reduce fraud. Flint (1995) observes that for ticketless travel to become widespread in the airline industry, the electronic ticketing must, among other things, be protected from fraud. Chief among the hurdles to secure electronic ticketing are passenger resistance, creation of various standards, airport egress/security issues, fraud protection, and travel agent opposition. Experts warn that electronic ticketing contains loopholes that could allow for fraudulent ticket purchases using stolen credit cards.

An information security survey conducted by InformationWeek/Ernst & Young (CMP Media, Inc. 1996) found that security is one of the biggest concerns among corporate Chief Information Officers and that while most companies are using the Internet or intranet for vital business functions, many feel that the information security measures for both are ineffective.

In summary, information technology that is not usable, scalable, interoperable, reliable, and secure creates barriers to the acquisition and implementation of IT in service industries. Further, the provision of these attributes is subject to the market failures discussed above because their providers face economic barriers in technology, development, and implementation. An extensive literature review, and quantitative estimates of service sector under investment reported in Chapter 4, suggest that the barriers discussed above are being experienced throughout the service sector. Our case studies of specific industries (Chapters 5-8) further indicate that these barriers are causing significant underinvestment in IT.

3.3 PUBLIC SUPPORT OF THE TECHNOLOGY INFRASTRUCTURE

We have described a number of types of barriers to the acquisition, development, and use of IT and provided examples of each type. Public policy can reduce these barriers and thereby improve the development and transfer of technology. Effective public policy reduces barriers to technology by improving appropriation of returns and reducing risk. Even if the private sector makes a maximum effort to deal with IT in an infrastructure-poor environment, market failures could not be completely removed. Market failure occurs in the dynamic sense because of the divergence of private and social perspectives concerning the expected returns to investment. Private firms do not appropriate all of the returns to their investments and they perceive more risk than society perceives; hence, they underinvest in the new technology that could create the environment for a better use of IT.

Formulating public programs to support technology infrastructure requires a three-part process: the development of policy rationales; strategic planning (involving government and industry); and economic impact assessment. Identifying and characterizing systematic market failures is central to the first part of this process. (Tassey, 1997)

Having established in Chapters 1 and 2 that the service sector contributes significantly to economic growth, and that service sector outputs are increasingly technology-intensive, the next step is to identify and characterize the nature and magnitude of underinvestments that occur as a result of the specific barriers to technology development and implementation discussed above.

Once identified, it is also important to categorize barriers according to the most appropriate policy response. Some types of market barriers are very general, affecting all technology development and implementation activity. These types of barriers can be effectively addressed through R&D tax credits or capital gains taxes. NIST, however, is particularly interested in identifying barriers that arise from a market's or a technology's immaturity, its degree of publicness, or its potential to reduce market transaction costs. The source of the barrier determines the appropriate policy response. (Tassey, 1977)

Underinvestments that arise from spillover barriers, interoperability barriers, information sharing barriers, and barriers arising from the necessarily shared nature of test and verification techniques are most effectively addressed through direct government funding of infratechnology development programs. Joint government-industry funding, on the other hand, is the most effective policy response to underinvestments that arise from recognition barriers, time-to-market barriers, and barriers associated with excessive competition among developers or users. This policy response framework will inform much of the case study analysis presented in chapters 5-8.

Once barriers are identified and characterized, their significance needs to be assessed. Industry participation is essential at this stage because industry is the principle source of market insight and viable technology programs require industry support. It is often very difficult to convey the nature and importance of the technology infrastructure to policy makers. While this infrastructure is central to the competitive strength of industries, it is often only appreciated by those with a detailed and sophisticated appreciation of the institutional system that sustains technology development and implementation. Industry participation in the process of identifying and characterizing the focus of technology programs, as well as their costs and benefits, add immeasurably to the credibility of program planning and, ultimately, the viability of program execution.

The following chapters are intended to support NIST's policy formulation process with a detailed assessment of specific barriers to technology development and implementation in the service sector. The scope of service sector's underinvestment in IT is estimated and specific barriers are identified and characterized through detailed case studies involving senior technology managers in high-tech service industries. It is our intention to make a contribution to the development of policy rationales for NIST's engagement with the service sector and to do so in a manner that at least facilitates progress toward the second stage of the policy analysis, strategic planning.

3.4 CONCLUSION

The role of the market failure concept is central to the analysis of public policy. This is especially so regarding public technology policy because of the widely shared understanding that investments in science and technology are subject to serious barriers and market failures. We have reviewed the concepts of market failure, underinvestment, and barriers to technology, and explained their relationships. We discuss eight distinct barriers to technology development and use, and provide examples from across the service sector as well as technical performance barriers. Finally, these barriers can be related to the technology policy instruments available to NIST. The conceptual apparatus developed in this chapter is core to the in-depth analysis of sources and uses of technology in the three industries selected for case study. (Chapters 5-8) It is also central to the policy discussions and recommendations that follow the case studies. (Chapter 9)

4. STATISTICAL ANALYSIS OF ECONOMIC PERFORMANCE AND MARKET FAILURE IN THE SERVICE SECTOR

4.1 INTRODUCTION

Available statistics and trade literature provide a useful overview of the broad dimensions of technology development and implementation in the service sector. Based on this information we are able to articulate a number of important issues:

- Information technology appears to be at the heart of technological change in the service sector.
- Technology development occurring within the service sector appears to be dominated by the communications services and the computer services industries. IT and IT-related technologies comprise an important element of the complete portfolio of technologies developed within these two service industries so that as much as half of all service sector R&D is devoted to IT.
- The vast majority of technology used in the service sector originates in the manufacturing sector and significant service sector resources are expended to implement this technology.
- The professional trade literature describes pervasive technology development and implementation barriers that can be interpreted from both a market incentives perspective and the user's perspective.

However, while available statistics and literature are often suggestive of the seriousness of barriers to technology faced by service sector firms, they are insufficient for assessing the nature and extent of the barriers to technology in the detailed and systematic fashion necessary for NIST planning purposes.

In this chapter, we begin to "drill down," systematically, to understand the extent to which service sector firms are experiencing barriers to technology and to understand what effect, if any, these barriers are having on the competitive performance of service sector firms. As part of our statistical analysis, we explore the usefulness of various types of data for capturing important aspects of technology development and use in the service sector.

The statistical analyses presented in this chapter are rich is some dimensions and wanting in others. We are able to suggest the possibility of an underinvestment in IT, but we are also able to show that this underinvestment trend is not characteristic of all service sector firms. In fact, we provide some evidence that barriers to the adoption and implementation of IT may be overcome, in part, by firms through certain institutional activities and arrangements. However, we conclude that definitive answers cannot be determined from a broad-based statistical analysis, such as we present here, without specific case-based information The combination of the analysis in this chapter together with the in-depth case-based information in Chapters 5-8, begins to develop a relatively detailed picture of the barriers to technology that exist in the development and implementation of IT.

There is a growing literature documenting the increase in investment in information technology and the lack of a measurable productivity response. This is especially the case among service industry firms. As Brynjolfsson (1993, p. 67) notes:

> The relationship between information technology (IT) and productivity is widely discussed but little understood. Delivered computing power in the U.S. economy has increased more that two orders of magnitude since 1970 ... yet productivity, especially in the service sector, seems to have stagnated.

In this chapter, we estimate the IT-to-productivity relationship using a large cross-sectional and time series of data assembled by Brynjolfsson and Hitt, arguably the most complete and widely-cited data base related to IT in service sector firms. We ask, based on these data, if statistical-based analyses are capable of quantifying an underinvestment in IT. [40,41] If so, then we ask if such an econometric approach is sufficiently robust to identifying particular technology barriers at a level detailed enough to inform technology policy decisions on NIST's part.

For readers who are only interested in the outcome of the statistical investigation, the following section 4.2 provides a brief summary of the statistical analysis and its conclusions. The reader so inclined can skip from section 4.2 to the case study analysis presented in Chapters 5-8. For those interested in the more detailed methodological aspect of the analysis, these are presented in sections 4.3 - 4.5.

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[40] We use the term "statistical-based" to refer to conclusions reached through traditional econometric analyses germane to economic studies. Our use of that term is not intended to suggest that case-based studies are neither systematic in design nor quantitative in nature. In fact, the primary conclusions set forth in this report are derived from case analyses. Rather, we segment the empirical investigations in this report into two broad categories: statistical (econometric) in this chapter and case-based in Chapters 5-8.

[41] In sections 4.4 and 4.5 we supplement the Brynjolfsson and Hitt data set with information from other data sets related to patenting activity and collaborative research activity, respectively.

4.2 INVESTMENTS IN INFORMATION TECHNOLOGY: ANALYSIS IN BRIEF

4.2.1 Quantifying the Barriers to IT Investment

Using standard statistical techniques and detailed data from 300 service sector firms we can make some important observations about the nature and significance of barriers to IT investment in the service sector.

Our analysis shows that a $1 investment in IT capital contributes substantially more to value added than a $1 investment in non-IT capital. A $1 increase in investment in IT capital yields a $1.96 increase in value added in each period. In other words, these results imply that the rate of return on IT capital is 196 percent. A $1 investment in non-IT capital yields $0.11 each period, or a rate of return of 11 percent.

This finding is interpreted to suggest that firms in service industries are, on average, realizing sizable positive returns to their investments in IT. Certainly, 196 percent is greater than the hurdle rate used in most private sector firms for R&D investment decisions, perhaps by a factor of about 16. If, following best practice, firms choose sequentially from a potential list of investment projects — first those with the highest rate of return, then the next highest rate of return, etc. — a rate of return on IT capital projects of 196 percent (relative to 11 percent on non-IT capital), suggests that "something" is preventing firms from making highly productive investments in equipment embodying IT.

The statistical analysis that supports this finding is based on traditional production theory drawn from the economics literature and begins with a model of how various resources affect the economic performance of the firms being studied. We begin by statistically estimating the values of ρ_o through ρ_3 in the following model:

$$\ln(VA) = \rho_0 + \rho_1 \ln(L) + \rho_2 \ln(ITK) + \rho_3 \ln(NITK) + \varepsilon$$

In this model, competitive performance is measured as value added (VA); the resources used to create VA are labor (L), IT capital (ITK) and non-IT capital (NITK). We statistically estimated the values of ρ_o through ρ_3 and used that information to calculate the productivity of IT and non-IT capital. We find that the $1 invested in IT capital is significantly more productive than $1 invested in non-IT capital and that the discrepancy suggests barriers to greater investment in IT capital. This finding is perfectly consistent with the evidence presented in preceding chapters describing barriers to the development and implementation of IT; barriers that are preventing the greatest utilization of technology, and therefore, we believe, barriers to the fullest growth and development of the service sector.

4.2.2 Quantifying the Strategic Response to IT Barriers

Having established a quantitative measure of the scale of the barriers faced by service sector firms, we asked what standard statistical techniques could tell us about the effectiveness of actions taken by firms to overcome investment barriers. What makes this question most difficult is the paucity of reliable indicators of firms' strategic behavior in the realm of technology.

Firms react to technology barriers in a number of ways: they invest time and resources to cope with the problems thrown up by the barriers; they increasingly invest in internal technology development projects; they engage in collective R&D efforts with other members of their industry; and they become involved in industry-wide activities such as standard-making and industrial association events focused on addressing technology issues. In an attempt to quantify some of these activities, and to understand their competitive impact, measures of collaborative research and patenting practices were introduced into our statistical analysis.[42]

Research Joint Ventures. Our analysis shows that service sector firms engaged in research joint ventures (RJVs) perform more competitively, and are investing more in IT, than firms that are not so engaged. This suggests that firms are using collaboratively-generated R&D knowledge to increase the efficiency with which they utilize all forms of technology, IT included.

To explore whether service sector firms are systematically relying on collaborative research relationships to eliminate elements of risk associated with the acquisition and implementation of IT, we estimate the following version of our statistical model:

$$\ln(VA) = \rho_0 + \rho_1 \ln(L) + \rho_2 \ln(ITK) + \rho_3 \ln(NITK) + \rho_4 D\_RJV + \varepsilon$$

where the value of D_RJV is 1 if the firm participated in an RJV in a particular year, and 0 otherwise.

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42 Neither patenting activity nor RJV membership are thought to be the only response to the technology barriers faced by service sector firms. We regard them merely as readily quantifiable evidence that firms are engaged in self-conscious, strategic, conduct to mitigate barriers to technology development and use. We suspect that if they are so-engaged, they are

The estimated coefficient on D_RJV (ρ_4) is positive and statistically significant as is the estimated coefficient on IT capital (ρ_2). In fact, ρ_2 increased nearly 70 percent over a baseline calculation indicating that the productivity of IT capital increases substantially for service sector firms involved in collaborative research. We also observe that firms engaged in RJVs invest more in IT than firms not so engaged (2.86 percent of value added compared to 1.98 percent). This suggests that service sector firms that are involved in collaborative research relationships have found some solutions to IT barriers that makes their more intensive investment in IT profitable when compared to service firms that are not involved in collaborative efforts.

Patents. Patents are another indicator of firms' attempts to overcome barriers to technology development, especially the appropriability problems that plague such efforts. Our analysis indicates that systematic and focused technology development efforts by firms (as indicated by clusters of inter-related patents) has a positive impact on firm performance. However, the relationship between such technology development activities and IT investment cannot be adequately explained.

To explore whether service sector firms are systematically relying on internal innovation efforts to overcome barriers to IT investment we examined the total amount of patenting activity as well as the integral nature of that activity. Accordingly, the following statistical model was evaluated:

$$\ln(VA) = \rho_0 + \rho_1 \ln(L) + \rho_2 \ln(ITK) + \rho_3 \ln(NITK) + \rho_4 SELFCIT + \rho_5 \ln(TP) + \varepsilon$$

where SELFCIT represents the percent of all citations in a company's portfolio of patents that link to its own prior patents, and ln(TP) represents the total patents issued to a firm.

The results of our statistical analysis show no evidence that the total amount of patenting activity (or the underlying R&D activity that patenting behavior represents) contributes, in a statistical sense, to firm performance (in terms of VA). The coefficient (ρ_4) for self-citation is positive and statistically significant. The direct productivity impact of self-citing activity on IT capital could not be discerned.

In summary, we have quantified the economic impact of barriers to IT investments by service sector firms and find the rate of return on IT capital several times higher than expected. This indicates that

also engaged in other mitigating activities with respect to technology.

firms are somehow being prevented from investing in IT. Otherwise investment in IT projects would have proceeded and pushed the rate of return on such projects closer to the typical return on investment project. We can also distinguish types of conduct on the part of service sector firms that appear to mitigate these barriers to IT investment. Service sector firms that systematically attempt to protect their investments in technology development, and those that participate in collaborative R&D activities, are investing more in IT capital than service sector firms that do not engage in such activities.

While these results are important and constitute a logical first step in policy assessment, statistical analysis of even the best available firm-level data is insufficient to provide the detailed level of insight into technology barriers and their causes required for NIST planning purposes. For this, in-depth case study analysis is required. The following chapters provide such analysis for selected services sector industries.

4.3 INVESTMENTS IN INFORMATION TECHNOLOGY

4.3.1 The Empirical Model

Our analysis begins with a general conceptual representation of the functional relationship between a firm's inputs and its output. We characterize output as value added, VA, and inputs as labor, L, and capital, K, in the following way:

$$VA = F(L, K) \tag{1}$$

where VA can also be viewed as a measure of the economic performance of the firm.

This is a common starting point is the empirical literature related to productivity growth and returns to investments in technology. Equation (1) is no more than a stylized representation of the fact that a firm combines labor (L) and capital (K) to produce output or to add value (VA) in production. In fact, in a general sense, equation (1) is simply the production stage of the technology-based economic growth model originally presented in Figure 4-1.

As is common in the economic, and particularly in the productivity growth literature, a specific functional form is assumed for equation (1). A mathematical specification is needed in order to derive certain economic properties of the general production function. The mathematical specification often used is called a Cobb-Douglas production function:

(2) $$VA = A\, L^{\alpha}\, K^{\beta}$$

where A is a disembodied shift factor, and α and β are the relative share of income distributed to labor and capital, respectively.[43] Our choice of this Cobb-Douglas specification is not arbitrary. The mathematical form of the production function in equation (2) represents the simplest and most commonly used specification. Labor's relative share of income is α, and capital's relative share is β. These are referred to by economists as "elasticities," meaning measures of responsiveness.) Alpha represents the percentage change in value added attributable to a given percentage change in labor (i.e., a 10 percent increase in labor, all else remaining constant, leads to an α percent increase in value added). A similar interpretation holds for capital's relative share, β. So defined, quantitative estimates of L and K will be related to statistical measures of the productivity of labor and capital, respectively. (In equation (6) below, the value of ρ_1 corresponds to α and the values of ρ_2 and ρ_3 correspond to β.)

Fundamental to this study is the fact that the stock of capital used in service sector firms is not homogeneous as represented by the variable K in equations (1) and (2), rather, the stock of capital is heterogeneous being separable into capital that embodies information technology, ITK, and capital that does not (non-information technology embodied capital), NITK, thus:[44]

(3) $$K = ITK + NITK$$

This distinction is captured in Figure 4-1.

Based on equation (3), equation (2) can be rewritten as:

(4) $$VA = A\, L^{\alpha}\, ITK^{\beta_1}\, NITK^{\beta_2}$$

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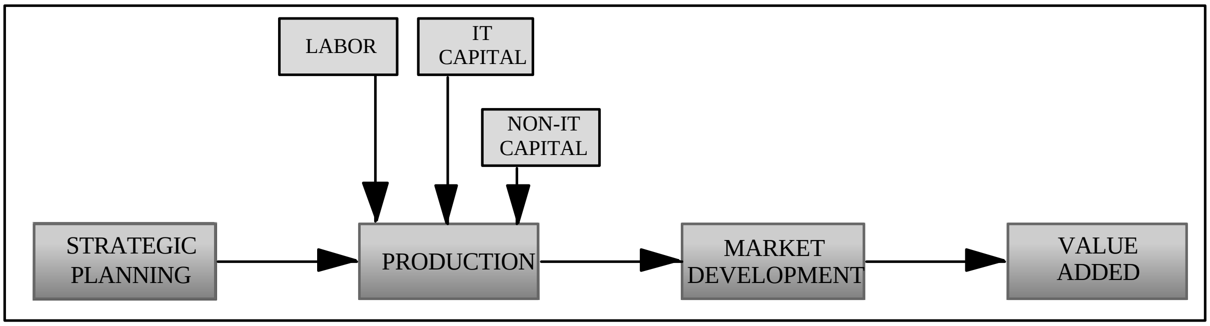
[43] See Link (1989) for a review of the relevant literature. The Cobb-Douglas specification is discussed here for ease of presentation. However, generalized transcendental logarithmic (translog) production functions are frequently referred to in the literature. While the econometric results presented below are for the Cobb-Douglas model, translog estimates were also made (not presented). The findings from the latter provide little if any additional insight into the question at hand.

[44] For a more detailed discussion of these concepts, see Brynjolfsson and Hitt (1995, 1996b, 1996c).

Figure 4-1. Disaggregation of Capital Stock in Service Sector "Production" Model



And as with equation (2), β_1, is the relative share of income distributed to information technology capital and β_2 is the relative share of income distributed to non-information technology capital.

Taking the natural logarithm of both sides of equation (4) for the purpose of deriving a relationship that can be estimated econometrically:

(5) $$\ln(VA) = \ln(A) + \alpha \ln(L) + \beta_1 \ln(ITK) + \beta_2 \ln(NITK)$$

and introducing a normally distributed random error term, ε, into equation (5), an econometric specification results:

(6) $$\ln(VA) = \rho_0 + \rho_1 \ln(L) + \rho_2 \ln(ITK) + \rho_3 \ln(NITK) + \varepsilon$$

Equation (6) is a common starting point for a statistical analysis. Given a set of firm data on value added, labor, information technology capital, and non-information technology capital, one can estimate the values of ρ_o through ρ_3. One can then infer the productivity impact of investments in IT on the basis of the size and statistical significance of the estimated regression coefficient on the regressor ln(ITK), namely ρ_2. From equation (6), ρ_2 is the relative share of IT capital also known as the output elasticity of the stock of IT capital, the percentage change in value added divided by the percentage change in IT capital. This estimated elasticity, multiplied by the ratio of VA to ITK yields a calculated value of the marginal product of IT capital. Calculating the marginal product of IT capital using mean values of VA and ITK is:

$$MP_{ITK} = \rho_2 (VA_{mean} / ITK_{mean})$$

Certainly, if investments in information technology are at a level that enhances the performance of service sector firms, then the estimated coefficient on ln(ITK), ρ_2, will be positive and statistically different from zero.

4.3.2 The Data and Empirical Results

Our data was constructed from information contained in the Standard and Poor's Compustat data file. That file consists of production and financial data for all publicly-traded companies in the United States, assembled from primary information reported in companies' annual reports, 10-K forms, and similar public documents. Each firm is also assigned a 4-digit Standard Industrial Classification (SIC) code which was used to segment the firms by sector.

For the purposes of this study, data in the Compustat file relate to firms' inputs and outputs, specifically, value added, the firm's stock of labor, and the firm's total capital equipment investments. These reported data were supplemented with survey data collected by Brynjolfsson and Hitt.

The Brynjolfsson-Hitt data set, arguably the most complete and widely-cited data set related to investments in information technology, is a quasi-balanced panel across service industries. Data exist for nearly 300 firms covering the years 1987 through 1994.[45] Hence, the final data set captures cross-service sector firm performance over a period of 8 years. Table 4-1 shows selected descriptive statistics on the variables defined by equation (6).[46,47] And, Table 4-2 shows the number of observations in the panel, by year. Hence, our estimation of equation (6) utilizes 2,247 observations (where each year of data is controlled for, in a statistical sense, by a time dummy).

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[45] A complete discussion of database construction issues is found in Brynjolfsson and Hitt (1995, 1996b, 1996c).

[46] To preserve the proprietary nature of this data set, Brynjolfsson and Hitt performed the statistical analyses described below.

[47] While the value of ITK may appear low relative to other values, recall from Chapter 2 that direct investments in IT represent only a small part of the total IT-related expenditures. In fact the literature suggests that, in general, IT-related implementation costs can be 5 times direct IT cost.

Table 4-1. Brynjolfsson-Hitt Data Set: Descriptive Statistics (n=2,247)

Variable	Mean
VA	$915.99
L	492.75
K	$1,772.24
ITK	$14.01
NITK	$1,737.15

Note: Value added and both capital stock measures are in millions of $1990; labor is in units.

Table 4-2. Description of the Brynjolfsson-Hitt Panel, by Year (n=2,247)

Year	No. Observations
1987	235
1988	241
1989	257
1990	261
1991	277
1992	294
1993	324
1994	358

The least-squares regression results from the estimation of equation (6) are in Table 4-3. The regression results clearly demonstrate that all three of the inputs into production have, averaged across all firms in the data set, a productive impact. In other words, ρ_1, ρ_2, and ρ_3 from equation (6) are not only positive but they are statistically significant. Of particular emphasis is the statistical importance of investments in IT on firm's performance. The estimated coefficient on the IT capital stock variable, ρ_2, is positive and statistically significant at the 0.01 level. Also held constant in the version of equation (6) estimated and presented in Table 4-3 are industry and time dummy variables. Industry dummies correspond to the two-digit SIC service industry of the firm, and time dummies account for the year of the observation.

Compared to a regression corresponding to equation (2) above in which the capital stock is not decomposed into information and non-information technology, the estimated coefficient on ln(NITK) in

Table 4-3 is only slightly less than that on ln(K), 0.21 from equation (6) compared to 0.22 from equation (2); and correspondingly, little overall explanatory power is gained from the decomposition of the capital stock as evidenced by R^2 remaining virtually unchanged. (The reader is warned not to infer from this any information about the relative productivity impact of IT. To do that, calculated marginal products, rather than estimated elasticities are needed, as discussed below.)[48]

Table 4-3. Least-Squares Regression Results for Equation (6)
(t-statistics in parentheses; n=2,247)

Variable	Equation (6)
ln(L)	0.69 (65.33)
ln(ITK)	0.03 (4.82)
ln(NITK)	0.21 (21.67)
industry dummies	yes
time dummies	yes
R^2	0.93

We hypothesize the regression results in Table 4-3 as the baseline results from which we generalize about service sector firms' investments in IT and resulting productivity gains. Not only is the estimated coefficient on ln(ITK) positive and significant, but also the results indicate that a $1 investment in IT capital contributes substantially more to value added than a $1 investment in non-IT capital, *ceteris paribus*. The calculated marginal product for IT capital, based on the regression results in Table 4-3, is 1.96 compared to 0.11 for non-IT capital. A $1 investment in IT capital yields $1.96 each period, or if there were no depreciation that yield would continue in perpetuity, and hence in that sense the literature would sometimes refer to this results as implying that the rate of return on IT capital is 196 percent. A $1 investment in non-ITK yields $0.11 each period, or for the case of no depreciation, a rate of return of 11 percent. This finding is interpreted, to suggest that firms in service industries are on average realizing sizable positive returns to their investments in IT.

[48] As discussed at the end of the previous section, additional information (the ratio of VA to ITK) is needed to understand the productivity impact of IT investments.

Absent information on the long-run return on investment in IT, we cannot say with certainty whether firms are underinvesting in IT. Compared to the rate of return earned by manufacturing firms on their self-financed R&D capital however, 196 percent is high, by a factor of four, thus suggesting that service sector firms are indeed underinvesting in the technology.[49] And certainly, 196 percent is greater than the hurdle rate used in most private sector firms for R&D investment decisions, perhaps by a factor of sixteen.

In an effort to examine in greater detail the nature of the market failure that leads to this quantified underinvestment in IT, two alternative market concepts are investigated: participation in research joint ventures, viewed as an industry mechanism to overcome barriers to the development and use of new technical knowledge; and patenting behavior, viewed as an effort by firms to develop and exploit marketable technology. Participation in research joint ventures is considered in the following section. Patenting behavior in considered in section 4.5.

4.4 COLLABORATING IN RESEARCH AS AN INDICATION OF MARKET FAILURE

Economic theory as well as case-based literature suggests that firms participate in collaborative research ventures in an effort to, among other things, increase the speed with which generic technological information is created. All members of the venture, and generally non-members from the industry, benefit from having this information sooner, and at a lower cost, than if each member conducted research on its own.[50]

More specifically, Link and Tassey (1987, pp. 10-11) hypothesize that RJVs are formed as part of an overall strategy for technology-based competition:

> Technologies are evolving, penetrating, and maturing faster. This comes from more rapid advances in generic technology by foreign industries based on government support and cooperative industrial research, as well as from more intense world competition which brings about a faster penetration and maturation of products. Similarly, cycles are evolving at faster rates. . . . In other words, firms can no longer rely solely on an innovative strategy based on internal R&D. A broader strategy is needed. . . . [S]uccessful technology-based strategies . . . must rest more and more on the realization of economies

[49] For one summary of the R&D rate of return findings in the literature, see National Science Board (1996).

[50] See Link and Bauer (1989) on this point.

> of scope . . . [T]he functional areas within the firm must be efficiently integrated and the firm must be integrated within a complex infrastructure which includes other firms in its domestic industry.

And, there is growing evidence that in the absence of this type of arrangement, competitive-requisite research might not be conducted by anyone, or if so it might not be done in a timely manner.[51] As such, collaborative research efforts are important not simply for U.S. industries to continue to compete, but for them to compete more effectively in technologically-progressive global markets.[52] Thus, the formation of an RJV can be interpreted as an institutional arrangement designed to overcome selected barriers in technology that could lead to market failure.

Meltzer (1993) notes that some service sector firms, in an effort to overcome the aspects of technology-specific risk, are of the opinion and practice that collaborative R&D development of appropriate IT products, services, and environments is essential for generating sustained economic growth.

Congress approved the National Cooperative Research Act of 1984 (PL 98-462) and its 1993 amendment, the National Cooperative Research and Production Act (PL 103-42) in an effort to stimulate collaborative research.[53] Firms seeking antitrust indemnification under these Acts are required to file notification of their collaborative intentions with the Department of Justice, and this information is made public through notices in the *Federal Register*. RJVs gain two significant benefits from such voluntary filings: if subjected to a criminal or civil antitrust action, they are evaluated under a rule of reason that determines whether the venture improves social welfare; and if found to fail a rule-of-reason analysis, they are subjected to actual rather than treble damages.

The COllaborative REsearch (CORE) database on research joint venture (RJV) activity was constructed from information in *Federal Register* filings for use by the National Science Foundation.[54] Through the end of calendar year 1995, 561 separate RJVs have been filed with the Department of Justice as reported in the *Federal Register*.[55]

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51 See Link (1996b) for documentation of this for selected RJVs.

52 See Link and Tassey (1987).

53 See Link (1996a) for background information on these initiatives.

54 See Link (1996a) for a detailed discussion of the construction of the CORE data base.

55 RJVs must re-file if their membership changes or if the scope of their activity changes. Such refilings are not treated as new

An inspection of these filings, by sector, reveals that the prevalence of RJV activity is greater among manufacturing sector firms compared to service sector firms. But, there is year-by-year variability in the percentage of RJVs filed by firms in each sector. See Table 4-4,

Table 4-4. RJVs Formed by Year
(n=561)

Year	% Service Sector
1985	26% (of 50 filings)
1986	6% (of 17 filings)
1987	27% (of 26 filings)
1988	32% (of 31 filings)
1989	26% (of 27 filings)
1990	37% (of 46 filings)
1991	27% (of 62 filings)
1992	32% (of 59 filings)
1993	26% (of 72 filings)
1994	8% (of 63 filings)
1995	16% (of 108 filings)

Source: CORE database

To explore, in a rather general fashion, whether service sector firms are relying on collaborative research relationships in a purposeful way to eliminate elements of risk associated with the acquisition and implementation of IT, we estimate the following model:

$$\ln(VA) = \rho_0 + \rho_1 \ln(L) + \rho_2 \ln(ITK) + \rho_3 \ln(NITK) + \rho_4 D\_RJV + \varepsilon \quad (7)$$

where D_RJV is a binary variable equal to 1 if the firm participated in an RJV in a particular year, and 0 otherwise.[56]

collaborative research arrangements in the CORE data base.

[56] The RJV data come from the CORE data base and supplementary information provided by Vonortas (forthcoming). Recall that the sample of firms is a cross-sectional sample, pooled by year.

For the sample of service sector firms, about 7.2 percent have been involved in at least one RJV over the relevant years, as based on information in the CORE database.

Owing to the binary nature of the D_RJV variable and its systematic cross-industry variability, equation (7) was estimated with a constant term rather than a vector of industry dummies. As shown in column (1) of Table 4-5, the estimated coefficient on D_RJV is positive and statistically significant at the 0.01 level, as is the estimated coefficient on IT capital. In fact, the estimated regression coefficient on ln(ITK), and hence the marginal product of IT capital, has increased nearly 70 percent over that calculated from the baseline model in equation (6) (Table 4-3) ó 0.03 compared to 0.05.

Table 4-5. Least-Squares Regression Results from Equation (7)
(t-statistics in parentheses; n=2,247)

Variable	Equation (7)	Equation (7a)
ln(L)	0.71 (81.17)	0.71 (81.01)
ln(ITK)	0.05 (6.82)	0.05 (6.75)
ln(NITK)	0.18 (27.47)	0.18 (27.46)
D_RJV	0.10 (3.22)	0.10 (31.04)
ln(ITK)*D_RJV	—	0.00073 (0.04)
constant	0.94 (20.13)	0.94 (20.00)
time dummies	yes	yes
R^2	0.91	0.93

Regarding the significance of the estimated coefficient on D_RJV, the results shown in Table 4-5 support the view that collaborative research does indeed contribute to value added.[57] We interpret the calculated increase in the value of the marginal product of IT capital to suggest only that equation (7) is possibly better specified than was equation (6). Again, statistics confirm that service sector firms are underinvesting in IT as evidenced by apparently above normal returns to IT capital.

To explore further the relationship between RJV activity and the productivity of IT, we re-estimated equation (7) with an interaction term, ln(ITK)*D_RJV, as an additional regressor so that

57 Link and Bauer (1989) documented the productivity gains and R&D efficiency gains associated with collaboration.

separate marginal products can be compared for each subset.[58] The results are shown for equation (7a) in Table 4-5. The regression coefficient on the ln(ITK)*D_RJV variable was not statistically significant, owing perhaps to multicolinearlty with the D_RJV term. Hence, these regression results are inconclusive.

But, we did compare the mean level of investment in IT by service firms participating in RJVs. For RJV-active firms (n=161) the mean annual investment level in IT is 2.86 percent of value added compared to 1.98 percent for the other firms (n=2,086). This suggests that service sector firms that are involved in collaborative research relationships have found some solutions to IT barriers that make their more intensive investment in IT profitable when compared to service firms that are not involved in collaborative efforts, or that these firms are using the collaboratively-generated R&D knowledge to increase the efficiency with which they utilize all forms of technology, IT included.

4.5 APPROPRIATING TECHNICAL KNOW-HOW: AN INDICATION OF MARKET FAILURE

The new information technologies that are affecting the performance of firms in the service industry, as evidenced from the literature discussed in Chapter 2, are typically developed by manufacturing firms. According to the case studies reported in Chapters 5-8, service sector firms purchase that technology and then augment it through their own RDT&E investments. Patenting activity is a means by which a firm can appropriate the benefits of these investments. The ability to appropriate technical information has been shown in studies of the manufacturing sector to enhance productivity growth.

The Brynjolfsson-Hitt data set can accommodate only a cursory examination of patenting activity in service industries. Only about 35 of the 300 or so service sector firms in the data set patented inventions over the 1987-1994 period (resulting in 270 of the 2,247 panel observations); thus, because we do not have relevant information to determine the extent to which this sub-sample is representative of overall service sector patenting behavior, the conclusions that follow are at best tentative. Albeit a small subset of the population of service industry firms, it nevertheless does facilitate an exploratory statistical examination in

[58] The "interaction term" is an extended version of regression equation (10). It's use facilitated our investigation of the effect of RJV participation on both value added and on the marginal product of IT for RJV-active firms compared to the marginal product of IT for non-RJV-active firms. From an econometric perspective, it is more efficient to examine both of the latter effects in a single equation. An "interaction term" is defined as the multiple of the product of two regressors. When D=0, ln(ITK)*D_RJV=0; when D=1, ln(ITK)*D_RJV=ln(ITK). When D=1 the impact of IT on VA in the sum of the regression coefficient on ln(ITK) plus the regression coefficient on the interaction term, ln(ITK)*D_RJV.

an effort to glean some indication of the nature of the patenting activity undertaken and the possible implication of that activity on investments in IT.[59]

To investigate such purposeful appropriability efforts among service sector firms, we estimate equation (8), a variation of equation (6):

$$(8) \qquad \ln(VA) = \rho_0 + \rho_1 \ln(L) + \rho_2 \ln(ITK) + \rho_3 \ln(NITK) + \rho_4 \ln(TP) + \varepsilon$$

where ln(TP) represents the total patents issued to a firm.[60]

The range of patents for these service sector firms over this time period is 5 to 2,638 with a mean of about 29.[61]

As reported in Table 4-6, the estimated coefficient on ln(ITK) for equation (6), for the sub-sample of patent-active service firms, is 0.20. This estimated coefficient is not significantly different from zero. (The reader should note that this is the same specification of equation (6) as above with a sub-sample of only 270 observations from patent-active service firms.) The regression results for equation (8) show no evidence that patenting activity (or the underlying R&D activity that patenting behavior represents) contributes, in a statistical sense, to output. In addition, these regression results show that the estimated coefficient on IT capital is statistically insignificant. In other words, patent-active service sector firm that invest in IT capital are either overinvesting in the technology, thus driving the marginal product of IT toward zero, or are using what technology they have in a grossly inefficient manner. If the former conjecture is valid, then firms in this sample are, on average, overinvesting in IT owing to their ability to appropriate the economic benefits from such investments. Stated differently, the inability of service sector firms to appropriate the benefits of investments in R&D needed to make information technology productive creates a market failure, and an underinvestment in IT results.

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59 And, to our knowledge this represents the first empirical effort of this type.

60 Underlying equation (8) is a production function like: $VA = AL^{\alpha}ITK^{\beta1}NITK^{\beta2}TP^{\alpha}$ where α is the relative share of the stock of patents. The intuition behind such a production function is that a firm's patent portfolio captures an independent - synergistic - aspect of its technological capabilities, and these capabilities add value in production.

61 Patent data were provided by CHI Research, Inc. (1996c).

In an effort to explore this result in more detail, an alternative patenting measure was constructed, namely an index of self-citations. A firm's patents typically cite prior academic literature and other patents, including its own prior patents. According to Narin (1991):

> [H]ighly self-citing networks of patents are a sign of company strength. In analyzing citation networks it is quite apparent that when a company has an important technological advance it will attempt to patent around that advance, to obtain defensive patents on the periphery of the advance, and to extend its scope by building on the invention in the key patent. Important patents are usually apparent not only as a single highly cited patent, but as clusters of patents, and companies that have a well-organized technology seem to have a larger number of highly linked patents. In this sense, at least, self-citation at the corporate level appears to be an indicator of strength in corporate technology policy, and certainly not one of weakness.

Thus, based on this observation by Narin, and his supporting research, we hypothesize that service sector firms that have a high self-citation ratio are those that are systematically engaging in patenting activity to appropriate new technology, recalling that the dominant technology in the service sector is IT.[62] Accordingly, we estimate the following two models:

(9) $$\ln(VA) = \rho_0 + \rho_1 \ln(L) + \rho_2 \ln(ITK) + \rho_3 \ln(NITK) + \rho_4 \, SELFCIT + \varepsilon$$

(10) $$\ln(VA) = \rho_0 + \rho_1 \ln(L) + \rho_2 \ln(ITK) + \rho_3 \ln(NITK) + \rho_4 \, SELFCIT + \rho_5 \ln(TP) + \varepsilon$$

where SELFCIT is the percent of the total citations of each firm's patents received that are attributable to the firm's citations of its own, previously patented technology.[63]

In the sub-sample, the mean self-citation ratio is 0.075 with a range of 0 to 0.67.

As shown in Table 4-6, the estimated regression coefficient on SELFCIT for equation (9) is positive, but only marginally significant. However, when the total patenting activity of each firm is also held constant ó as specified in equation (10) ó the size and the level of significance of the self-citation variable increases.

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62 Self citations are the percent of the total citations a firm's patents receive that are attributable to the firm's citations of its own, previously patented, technology. If a firm's portfolio of patents receives 100 citations and 20 of those citations are from the company's patents citing previously patented technology, then self-citation ratio is 0.20.

63 These data were calculated by CHI Research, Inc. (1996c).

This increase is not due to collinearity, as evidenced by an insignificant correlation coefficient. As reported for equations (10) and (8), the productivity impact of IT capital cannot be distinguished from zero.

Table 4-6. Least-Squares Regression Results for Equations (6), (8), (9) and (10)
(t-statistics in parentheses; n=270)

Variable	Equation (6)	Equation (8)	Equation (9)	Equation (10)
ln(L)	0.58 (8.31)	0.57 (8.27)	0.58 (8.21)	0.57 (8.13)
ln(ITK)	0.02 (0.84)	0.02 (0.67)	0.01 (0.45)	0.01 (0.26)
ln(NITK)	0.37 (5.90)	0.36 (5.82)	0.38 (6.60)	0.39 (6.17)
ln(TP)	—	-0.01 (-0.66)	—	-0.02 (-1.22)
SELFCIT	—	—	0.31 (1.40)	0.40 (1.72)
industry dummies	yes	yes	yes	yes
time dummies	yes	yes	yes	yes
R^2	0.94	0.94	0.94	0.94

We offer two possible explanations for the overall pattern of results in the regressions reported in Table 4-6 regarding self-citations. If indeed the technology being appropriated by the self-citing firms is related to IT, then the insignificance of the IT variable may suggest that these patent-active service firms, compared to all service sector firms ó Table 4-3 ó are able to overcome, through their purposeful technology development, barriers to the effective acquisition and implementation of IT.

Thus, we tentatively conclude that the results in Table 4-6 are suggestive of the fact that these self-citing firms are, in response to self-developed appropriable technology boundaries, overinvesting in information technology, thus driving its marginal return toward zero. Alternatively, the appropriable activities of self-citing firms are such that they drain the resources needed to effectively adopt and use IT, and thus the IT that is in place is simply unproductive.

While these competing interpretations cannot be resolved from this small sample of patent-active firms ó or from any data set that we are aware ó we do observe from the underlying data that the mean level of investment in IT by patent-active service sector firms is over two times that of non-patent-active service sector firms. That is, patent-active firms allocate, on average, a larger portion of their output to IT ó 2.27 percent of their value added to IT compared to only 2.11 percent in non-patent-active firms. This is consistent with the interpretation that firms that are systematically engaged in protecting technology development efforts with patents are overinvesting in IT.[64]

4.6 CONCLUSIONS

The statistical findings presented in this chapter complement the findings presented in earlier chapters. Whether one surveys the literature or examines econometrically broad-based data sets, available facts all point to the conclusion that, by and large, service industry firms are underinvesting in information technology, presumably due to various technology barriers.[65] Both sources lead to the same conclusion that to determine specific technology barriers that bring about these underinvestments, survey information and case-based information are needed. The following chapters are focused on developing such information for several key service sector industries.

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[64] Why they would be overinvesting is a perplexing question. It could be that service sector firms with well-developed research programs have more of a focus on the future; that they are operating in a more dynamic mode, as if they had already captured the revenues and market share their relatively high investments require to be economical. In economic terms these firms may be operating on their long-run average cost curve rather than their short run cost curves. This is a view that conforms to a Schumpeterian/Chandlerian view of the dynamics of technological competition. (See Lazonick, 1993) That the evidence in question pertains to the innovative activities of firms supports this perspective. A more conventional perspective would be that a marginal product of zero simply indicates that firms have overinvested, made bad investments, misused the investments made, or simply have not yet figured out that their returns are negative. The latter seems quite plausible given the pace of technological change and the difficulties associated with measuring the return on IT investments. (Brynjolfsson, 1993)

[65] The analysis presented above concerning firms' strategic conduct in the face of technology barriers (operationalized for statistical purposes as systematic patenting and participation in collaborative R&D organizations) suggests that service sector firms engaged in innovative activities are investing more in purchased IT capital than service sector firms that are not so engaged. But given that the vast majority of service sector firms have historically acquired their IT embodied in capital equipment, it seems prudent to make the generalization that service sector firms are underinvesting in IT.

5. CASE STUDY: BARRIERS IN TECHNOLOGY DEVELOPMENT AND IMPLEMENTATION IN THE RETAIL BANKING INDUSTRY

5.1 THE SIGNIFICANCE OF THE RETAIL BANKING SECTOR

In 1993, retail banking (conservatively measured as depository institutions) accounted for somewhat more than 3 percent of total private service sector employment. A broader slice of related industries, finance, insurance, and real estate ("FIRE") totaled 10.4 percent of service sector employment. (U.S. Department of Commerce, 1994)

Quinn, *et al*. (National Research Council), 1994, pp. 80-85) emphasize that the banking industry is a major factor in the economy. Updating and developing the statistics reported there, we find that the industry generated revenues (operating income) of $331 billion in 1994. Real U.S. commercial bank assets grew from $3.2 trillion in 1979 to $3.9 trillion in 1994; loans have grown from $1.8 to $2.3 trillion; and deposits have grown from $2.6 to $2.8 trillion. Concentration in the U.S. banking industry continues, as the number of banking organizations has steadily declined from approximately 12,500 in 1979 to 7,900 in 1994. Over the same period, the number of commercial bank offices grew from approximately 50,000 to almost 66,000; and the number of automated teller machines (ATMs) grew from nearly 14,000 to almost 110,000. Total employment has remained constant over the last 15 years at about 1.4 million employees. Profitability has improved. Return on equity for all banks was 14 percent in 1979, 10 percent in 1986, and 15 percent in 1994. (Berger, Kashyap, and Scalise, 1995)

Over and above its direct importance to the economy, the retail-banking sector has an indirect significance that makes it extraordinarily important. With other segments of the financial sector, banking mobilizes savings and allocates credit across space and time. It provides services that enable all firms and households to cope with economic uncertainties by hedging, pooling, sharing, and pricing risks. An efficient financial sector reduces the costs and risks of producing and trading goods and services and thus makes an important contribution to raising standards of living. (Herring and Santomero, July 1991, p.1)

> Banks mediate a wide range of commercial and personal transactions involving the exchange and investment of money, providing such services as loans, deposits, and trust services to individuals, small businesses and corporations. (National Research Council, 1994, p. 80)

The banking sector's intermediation in such transactions reduces their costs; and many of these transaction costs reflect attempts to overcome imperfect information and risk that cause market failures.

Moreover, the barriers to technology discussed in Chapter 3 cause underinvestment in technology in the banking sector. Thus, technological improvements in the banking sector hold the potential for reducing transaction costs associated with market failures throughout the economy. Actions taken to reduce the barriers and frictions to the development and implementation of technology in banking can provide considerable leverage in reducing transaction costs in the economy as a whole and thereby perfecting the workings of markets.

Banks have long been among the most prodigious consumers of information technology. Early on, Scherer observed that the financial services sector was among the major consumers of information technology "exported" from the manufacturing sector. (Scherer, 1982). A recent review reports a number of estimates of the level and rate of technology investment by the retail banking industry. According to one estimate, the level of investment in technology by commercial banks during the 1980s grew at a compound annual rate of 13 percent, then dipped to 2 percent from 1990 to 1992 and increased again to 6.5 percent in 1993. Total expenditures by banks on IT in 1993 is estimated at $15.3 billion. A separate survey shows that the compound annual rate of growth in investment in information technology by the entire banking industry from 1981 to 1989 was 27.9 percent, substantially higher than all but one of the other service industries surveyed. It has been reported that the financial services industry accounts for some 16 percent of the dollars spent globally on technology and information systems. (Whaling, 1996)

5.2 THE NATURE OF RETAIL BANKING TODAY

The retail banking industry in the United States is undergoing a dramatic restructuring, brought on primarily by competitive forces unleashed by deregulation and technological change. (Steiner and Teixeira, 1991) The banking industry was subjected to intense regulation (primarily the Pepper-McFadden Act of 1927 and the Glass-Steagall Act of 1933) enacted around the time of the Great Depression to stabilize the financial sector. These regulations prohibited interstate branching by national banks and gave each state control over intrastate branching. These regulations also imposed interest rate ceilings and separated commercial banking from investment banking.

This regulatory framework began to unravel in the late 1970s. Increased competition from "non-banks" caused consolidation, a restructuring of the business mix, a shift to consumer credit (vs. business loans), and a dramatic rise in technology investments to streamline banking processes.

The growth in bank non-interest income and non-interest expenses reflects many of these changes. Between 1979 and 1994, non-interest income rose from approximately 8 percent of operating income to approximately 26 percent, and non-interest expenses rose from approximately 32 percent of total expenses to 56 percent.

Banking analysts argue that non-interest expenses are a critical factor in banking industry dynamics, representing the industry's critical competitive resource. (Steiner and Teixeira, 1991, p. 18) Moreover, of non-interest expense categories, systems expenses are growing most rapidly. The number of ATMs — which are among the most obvious manifestations of these rising system technology expenses — has grown from 13,800 in 1979 to 109,080 in 1994. (Berger, Kashyap, and Scalise, 1995)

Accompanying these changes, banks have been changing their business mix, moving away from heavy reliance on business loans toward more profitable consumer lending and fee-based financial services. This type of consumer-oriented banking demands mass-information processing capability. Information technology is particularly effective at streamlining manually repetitive data-intensive tasks — exactly the kind found in the back offices of banks. Consolidation of banking assets among a smaller number of banks is another manifestation of these competitive changes. (Steiner and Teixeira, 1991)

Banks have focused on creating value with these system investments. Many new services depend on such investments. For example, rapid reporting of a corporate customer's global cash position, demand deposit account services including ATMs, the ability to shift between multiple accounts, and overdraft privileges are all linked to systems technology. These systems generally display economies of scale so that increasingly automated lines of consumer-oriented business are supporting fewer and fewer large commercial banks.

The banking industry is experiencing the third stage of its technology absorption — the stage that directly affects the bank-customer interface. The previous stages saw automation of, first, the back office and, secondly, the front office of banking operations. While the changes brought about in the first two stages have been dramatic, and are by no means complete, observers consider the third stage to be competitively critical. (Steiner and Teixeira, 1991) While the first two phases focused more on reducing the cost of bank operations, the latter focus on providing new and improved services to customers.

Systems investments already are increasingly focused on "retail delivery" (the bank-customer interface). Retail delivery infrastructure accounts for the largest single item of non-interest expenditure for most retail banks. (Bank Administration Institute, 1995) According to one estimate, approximately 33 percent of banking IT investments went to retail delivery, more than went to any of the major “back office” functions, such as data centers, departmental systems, telecommunications, and item processing.

To summarize, banking markets that were kept geographically localized by regulation and prior technology have been transformed into national and international markets. The transformation is occurring in what was a highly fragmented industry, oriented towards proprietary technology solutions. For banking industry technology managers, this has led to a multitude of incompatible bank technology offerings and serious “legacy” system integration challenges. (Whaling, 1996)

While investment in system technology has been substantial, industry watchers observe that banks have just begun to tap the potential of current and projected technologies to facilitate the shift toward an increasingly customer-driven industry. For example, while the use of Internet sites by banks has grown rapidly, customer confidence, generally, and security concerns, specifically, limit all but a relatively small number of banks to offering information and simple inquiry facilities for now. According to a recent banking industry study, while the majority (58 percent) of bank customers do interact with banks “remotely” (via phone and mail), 32 percent interact physically through a branch or an ATM, and only 10 percent interact electronically. (Bank Administration Institute, 1995) As we discuss below, all this is quickly changing as banks appear to be gearing much of their leading technology initiatives toward getting to the customer in a manner that preserves and expands the relative position of the retail banking segment of the larger financial services industry.

5.3 MAJOR COMPETITIVE ISSUES

Despite years of consolidation, retail banking is still highly fragmented. This fragmentation is perceived by industry representatives as a major factor affecting investment behavior of financial institutions. In our interviews with technology managers in the banking industry, fragmentation and an industry culture not experienced with cooperative strategies were frequently mentioned.

This fragmentation complicates the industry’s competitive response to the serious competitive challenge posed by the entry of non-bank financial firms, such as credit card companies and non-financial firms like software providers or utility companies with sophisticated bill payment capabilities, into markets historically served by banks. This competitive challenge — referred to as “disintermediation” — is considered quite serious by retail bankers — so much so that some industry analysts worry about the "long-term decline" of retail banking. While some counsel that the industry must "act or die." Others, acknowledging market share loss to nonbanks of a quarter to a third in major debt markets, point to the tremendous offsetting growth in these same markets as a positive sign for banks. (Whaling, 1996; Berger, Kashyap, and Scalise, 1995)

So fragile is the competitive situation in retail banking that the leaders of even some of the largest, most successful banks are afflicted by concerns about "fading into oblivion" as the result of the wrong move, or bad timing, with respect to technology decisions and investments. (Wall Street Journal, July 25, 1996)

What is perceived by bankers as the competitive onslaught from outside the banking industry comes at a time when the industry is entering a new phase in the long life cycle of its implementation of IT, and proceeding at what *The Economist* characterized as "warp speed." The profound nature of the challenges of coping with disintermediation and nonbank market entry, while also making critical technology choices, can be summed up by a fundamental strategic question that the banking industry is grappling with: what is a bank?

Enabled by new information and communications technologies, banks are attempting to reorient their focus toward customers — attempting to provide financial services wherever consumers are located. This requires implementation of very new capabilities — like assuring security of electronic banking over the internet and the reorientation and rethinking of existing systems and capabilities, such as accessing segregated databases using client-server technologies and developing new mathematical models for predicting risk.

Technology managers face a dizzying array of alternatives and options just in an attempt to "keep up" with currently available technologies, let alone tracking and planning for tomorrow's technologies. Of course technology is not standing still. The major competitive challenges for banks include:

- Anticipating customer requirements that are highly uncertain
- Solving cutting edge technology issues — such as internet security — in a manner that affords the reliability and confidence to which customers have become accustomed (as with telephone technology)
- Employing vintage technology in new ways
- Integrating all these potentially divergent thrusts into effective systems.

Despite a historical disinclination to collective action, banks now appear to be adopting new vertical and horizontal organizational strategies in order to confront competitive pressures and complex technological challenges. This is done, in large part, to tap all the capabilities that are required in the kind of technologically convergent environment represented by the evolving banking industry.

> Many industries are faced with increasingly merging and overlapping technologies. With multiple technological strands converging, it is incumbent upon firms to stay on top of these developments. A firm will succeed to the extent that it can cover a wider range of innovative activities, whether alone or in partnership with other firms. ... In a study of commercial banks it was found that the scope of new information technologies is contingent on the firm having developed linkages, particularly with firms whose industries provide complementary knowledge. (Harianto and Pennings, 1994)

Leading bank industry analysts argue that competing with technology is a very complicated undertaking and involves much more than simply trying to improve technology by keeping up to date with new computers. And in a fragmented industry like banking, with so many competitors and so much technology available from outside vendors, the competitive positioning of what is done with technology is all important. (Steiner and Teixeira, 1991, p. 192) This was emphasized by NationsBank CEO, Hugh McColl: “This thing,” he says, referring to technology, “is like a tidal wave. If you fail in the game, you’re going to be dead.” McColl is convinced that if he makes the wrong bet, or the right bet at the wrong time, his bank will fade into obscurity. (*Wall Street Journal*, 1996)

5.4 THE R&D FUNCTION IN BANKING

R&D strategy is increasingly important to the banking business. Banks have long been important users of IT and, as discussed above, technology has become one of the most important factors in the ongoing transformation of the banking industry. Still, the vast majority of technology utilized by banks is acquired as embodied technology in purchased equipment and software.

Banks have been important commercial customers for IT developers and have always been among the earliest users of IT. Key users of technology are often the originating source of the innovation process. (von Hippel, 1988) While the banking sector has not traditionally been a major source of IT innovation, they have been, and continue to be, involved in the development and implementation of technology. For example:

> Magnetic Ink Character Recognition (MICR) began in 1960 and allowed the first automated handling of checks. Bank of America developed the first MICR technology

> based on a study by Stanford Research Institute. Early computers of the 1960s (NRC 315s and 316s) could then sort checks and capture the check data automatically. (Steiner and Teixeira, 1991, p. 33)

Involvement in IT development appears to be increasing. Interviews with technology development managers of several large U.S. banks indicate that they now play an important instigating role as co-developers of technology.[66] They often serve to "get the ball rolling." For example, the R&D function of one large bank developed the software code for a voice data application. As part of a co-development arrangement, a major communications equipment manufacturer developed the corresponding hardware. The resulting hardware was implemented and also used as the basis for a formal voice data-related standard.

While technology development efforts such as this may be qualitatively important, they are quantitatively insignificant, according to interviews with bank representatives. With important current exceptions, banks tend to follow in the development of technology of all kinds, rather than lead. As discussed earlier, this problem of being outside the main locus of IT development activity contributes to the uncertainty banks face in formulating their technology strategies in response to changing market realities.

If we categorize all IT-related activities as either development or implementation, most IT-related activities in the banking industry are implementation related. One estimate put the ratio of implementation to development dollars at 30 to 1. And if "development" is understood to involve research & development (R&D) on the one hand, and test and evaluation (T&E), on the other, technology "development" in banking appears to be heavily weighted toward T&E.

According to one estimate, system expenses represent as much as 20 percent of total expenditures for large banks. (Steiner and Teixeira, 1991, p. 22) For 1994, that represents some $50 billion dollars.[67] Banks split their systems budgets into about 1/3 for hardware, 1/3 for software development and maintenance, and 1/3 for everything else. Most software development funding goes into maintenance leaving no more than 10 percent of total systems budgets for truly new initiatives. (Steiner and Teixeira,

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[66] Interviews were conducted with technology managers of the following major banks and banking organizations: Bankers Roundtable; ANSI, X9; Bank Administration Institute; Bank of Boston; Chase Manhattan; Huntington Bank; Citibank; CommerceNet.

[67] Berger, Kashyap, and Scalise, 1995, Table A.2 reports operating expenses for all commercial banks in 1994 as $253 billion.

1991, p. 34) This estimate of 10 percent for truly new initiatives is consistent with estimates from our interviews with large banks, where RDT&E was estimated at approximately 2 percent of total IT-related development and implementation expenditures.

The R&D-related activities of large banks are highly oriented toward pre-acquisition test and evaluation of IT hardware and software. In interviews with bank technology managers, evaluation and integration planning were persistent themes. Considerable effort is devoted to "kicking the tires" of existing IT hardware and software products, assessing and monitoring software service agreements, evaluating the applicability of IT protocols developed by standards-related organizations, and generally keeping abreast of a wide array of technological activities across an even wider array of technological specialties. In a large bank, an "advanced technology" group may consist of 15-20 employees.

Because of the volume of transactions that could be affected by mis-steps or errors in the implementation of an IT innovation, all process and product innovations are extensively tested and then piloted in various locations. The organizational interface between testing and piloting seems to be the functional boundary of the formal R&D functions within banks.

It also appears that an increasing amount of time is being spent in some form of collective industry activity, such as co-development efforts with hardware and software providers, and participation in collective technology development and coordination efforts. The Banker's Roundtable estimates that there are currently approximately 46 of these banking-related collective technology development and standards-related activities.

5.5 THE TECHNOLOGY LANDSCAPE

Our research did not discover anything that could be described as a banking industry technology "roadmap." While we can report on individual technology "visions," the industry has not articulated any kind of high-order consensus on where it is headed technologically, what it will cost to get there, nor what organizations "own" the responsibilities for what parts.

In retrospect, perhaps this is not surprising. Bank technology managers see the pace of technological change as so fast and furious that at best they can only "navigate rather than plan." A large number of separate banking-related collective organizations engaged in technology development and standards efforts may also be evidence of the uncertainty that grips the banking industry as a whole.

While trends indicate greater emphasis on technology at the interface of the bank and the customer (as is consistent with the characterization of banking as in a “third stage” of technology absorption), technological opportunities continue to occur at a rapid pace across the spectrum of applications, including innovations in back-office and front office processes as well as customer access new “product” offerings.

As mentioned above, this very broad spectrum of technology opportunities presents new demands on banks’ resources and causes complex integration problems as new technologies must be made to interoperate with “legacy” systems as well as other new applications. For example, banks need to understand and integrate technological advances that will allow customers more ready access to electronic banking. Today only 10 percent of today’s banking customers access banking services electronically, so that advances in “human-centric technologies” (such as speech recognition, 3-D graphics and animation, speech translation, pen device support, hand-writing recognition and touch screens) are expected to be needed to allow greater electronic access to a broader customer base, and provide them with new products and services.

Table 5-1 presents three broad categories of technology focus: customer channel access technology, customer information technology, and back-office technology. In each category we have allocated specific technologies that have been highlighted in our review of recent banking literature or in interviews with representatives of the banking industry.

Table 5-1. Banking Technology Focus Areas

Channel Access Technologies	Customer Targeting Technologies	Back-Office Innovation Technologies
• Authentication • Bank internet payment • Cryptography • Data compression • Electronic checks • Electronic commerce • Firewalls for internet tools • Fraud/biometrics • Java applications • Next-generation internet • Quality of service for multi-media applications • Screen phones • Set-top boxes • Speech recognition	• Client-server (integration of dispersed data bases) • Data-mining • Groupware applications • Software agents • Transaction-by-transaction targeting	• Distributed databases • Electronic supply chains • Hierarchical mass storage • Image technology • Open systems software • Workflow software

While all three categories of technology are obviously very important, and interrelated, in our interviews with banking technology managers, the emphasis seems to have been primarily on technologies that operate at the interface of the bank and the customer. Our interviews were conducted within the context of a hypothetical role for NIST in serving the banking industry so, to some extent, the emphasis speaks to the areas where banks feel there is scope for “outside” support. Lending support to this interpretation, we found that in reviewing technologies that fall into the customer targeting category — such as modeling, simulation, and mathematical algorithms — we obtained the sense that these were areas where the banks themselves had developed a great deal of expertise.

Within the broad category of channel-access technology, bank technology managers stressed security and network monitoring and control. Like the access technology generally, the objective of security and network control is confidence-building to improve and assure customer utilization of electronic channels.

An emphasis on channel access technology is also consistent with the view that the information technology that banks are grappling to implement is increasingly shifting the initiative for financial services *from* the bank *to* the consumer. In the "networked economy," as one observer calls it, where electronic channels are the standards for all types of transactions, banks perceive a need to provide banking services wherever the customers are to be found.

> As the consumer becomes more technologically sophisticated and accustomed to accessing on-line services, she will determine which channels to use to access her desired financial services, at her convenience. The banks must provide service on these channels or they risk being invisible to the customer. The customer will choose the products, services, and the channels she wants, from whichever provider best meets her requirements, with little or no loyalty to a particular financial institution. (Howe, 1996)

In such an environment, banks need two things overall: access to customers (hence the emphasis, we believe, on access technology) and product content. The latter, only the individual banks and their suppliers can provide. To be effective, the former requires collective effort.

The second important qualitative observation is that the banking industry appears to be especially interested in a number of specific technologies that have been identified by NIST as important to the development and implementation of IT and that are currently the focus of NIST activities, such as computer security, computer networking, and monitoring and control for large networks.

Table 5-2 presents the industry respondents' rankings of a list of important IT areas. Technologies were ranked according to the frequency with which they were identified as critical to the industry's future. Although small, the sample is comprised of senior technology managers. Consistent with the technology policy framework developed in Chapter 3 (regarding the appropriate policy response to the various types of market failures), it is possible to interpret the ranking of technology areas in terms of requirements for generic and infratechnology support.[68]

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[68] The list of technology areas ranked by industry technology managers contained ones in which NIST technical specialists felt there was an appropriate role for NIST and in which NIST was engaged in technical support activities. The list also contained technology areas that were considered more appropriate to private sector activity and where private sector activities were ongoing. Only technology areas that were considered critical to more than one company are included in the table presented here.

Table 5-2. Banking Industry IT Priorities by Technology Area and Type[69]

Technology Type	Technology Area	Rank
Generic Technology	Monitoring & control for large networks	1
	Set top boxes for interactive TV	2
	Design for speech recognition hardware/software	2
	Electronic commerce applications	2
	Distributed databases	2
	Operating systems and utilities	3
	Data management	3
Infratechnology	Cryptographic standards	2
	Firewalls & Internet-based tools	2
	Conformance test for crytographic standards	3
	Advanced authentication technology	3
	Network scaling	3
	Wireless communication	3
	Data compression	3

We make the following observations about these results. First, it appears that many of the priorities of the retail banking industry are shared by entertainment and health care industries. We suspect that the emphasis on interacting with the customer — for both entertainment and banking, the focus is "in the home"— is the source of this similarity. Both sectors appear to be focusing a great deal of attention on the Internet as a tool for communicating and transacting with the customer base. The policy significance to NIST of our findings concerning banking industry technology will be considered together with findings concerning the home entertainment and health care industries in Chapter 8.

As discussed in Chapter 3 (section 3.2), insight into technological impediments can be gained from knowledge about users' functional priorities regarding IT. Table 5-3 presents a banking industry perspective on the priorities assigned to IT performance characteristics.[70]

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[69] Respondents were asked to indicate which of 49 technology activity areas (identified in Perine, et al., 1996) were of critical importance to their industry's future. We emphasize that interviews were informal and covered a broad range of topics within a very limited interview period. Technical areas are ranked according to the cumulative number of times they were indicated as critical to the retail banking industry's future by interview respondents.

[70] Banking industry contacts did not respond to questions concerning the ranking of IT performance attributes. Table 5-3 is presented for purposes of consistency with the case studies of the home entertainment and health care industries presented in Chapters 6 and 7 respectively. The ranking is based on the authors' judgments following detailed interviews with

Table 5-3. Banking Industry Ranking of IT Performance Attributes

Characteristic	Rank
Usability	1
Security	2
Reliability	3
Interoperability	4
Scalability	5

5.6 BARRIERS IN TECHNOLOGY DEVELOPMENT AND IMPLEMENTATION

This section discusses phenomena in today's banking market place that are consistent with the logic of market failure. Serious information uncertainties and network or system integration problems pervade the banking industry and present significant barriers to technology implementation.

The sentiments expressed by NationsBank CEO McColl of acute uneasiness in the face of rapid technological change and rapidly-evolving IT system choices were echoed in our interviews with banking industry technology managers and is evident in the literature. The difficulty technology managers have in seeing past an 18-month planning horizon clearly affects the investments they make and how they make them. Coupled with what was characterized in our interviews as persistent problems of R&D project cost overruns (which can be reasonably interpreted as resulting from efforts to minimize cost projections to achieve acceptable projected hurdle rates), a picture emerges of a technology investment planning environment that is fraught with uncertainties and risks that make long-term technology issues very difficult to identify, much less to plan for and to allocate sufficient resources to.

An abundance of collaborative activities of various sorts is currently underway, to pool knowledge, to aid in the coordination of technological initiatives among horizontally- and vertically-related organizations, and to spread the costs and risks of technology planning and investment. At the root of these perceptions of high technological and business risk are a number of phenomena that result in uncertainty of about banking's technological future: the convergent nature of IT; the related fact that the locus of technological change is driven by forces outside the banking industry; organizational inertia in the banking industry itself; the inability to accurately predict customer response to "the networked bank;" and the host

banking industry technology managers.

of technological issues that continue to confuse IT development and implementation planning: technology specific challenges, technology insertion, interoperability, security, and usability. Clearly, the *information inadequacy* that accounts for a large class of market failures is at work in the retail banking industry. The "fog" that prevents a clear view of the banking industry's the technological future, the intense competitive environment, and the resulting redefinition of banking services are creating a very risky technology investment environment.

The root of the uncertainty confronting bank technology managers is the technological and industrial convergence that is part and parcel of the IT revolution, compounded by the systems nature of technology implementation in banking. For example, a recent analysis by the Bank Administration Institute, argues that banks are in the precarious position of being unable to anticipate technological and behavioral changes because they are reacting from the periphery, outside the industrial locus of IT development. (Bank Administration Institute, 1995) And in response, some of the most technologically innovative banks have organized numerous interorganizational alliances to pool technological knowledge and experience. (Harianto and Pennings, 1994) The IT convergence phenomenon is even reflected in the priorities of technology managers who regard their most important technological challenge to be one of integrating technology from disparate sources.

While increasingly in evidence today, interorganizational collaboration has been slow to materialize in the banking industry, according to industry sources. The historical experience of the banking industry has been partly responsible for the slow acceptance of collaboration. In addition to the regulatory framework that segregated markets geographically for many years, the industry's specific experience with ATMs was not a promising one. ATMs are still not considered as user friendly as they should be, and the interoperablilty of bankcards and ATMs is far from ideal. This same experience confronts forward-looking visions of the future of electronic banking. The "wildly inaccurate" projections of past waves of innovation have cultivated a "careful attitude" toward such novel opportunities as Internet banking. (Economist, 1996)

While technological convergence contributes to the uncertainty facing technology managers, the emerging "networked banking" highlights another important source of uncertainty: the presence of *network externalities and system integration problems*.

The bank can be described as a physical network, with nodes and branches. Increasingly, the banking network has transformed itself into a physical network of interoperating electronic information systems.[71] The future of banking appears to be a movement further in this direction with an increasing need for interorganizational interconnectivity, first within the banking and financial services industries and, increasingly, with other segments of the economy as well. Bankers' concerns about fragile dominance in the face of rapid technological change, interoperability, coordination, being "stranded" by investments in the wrong network, and anticipation of an uncertain consuming population are textbook indicators of an economic environment prone to network externalities and systems competition issues. With the consolidation that had been taken place in the banking industry, these networks are growing. And if the "networked bank" is to become a reality, banking organizations must be increasingly interoperable in a wider and wider set of technological applications. This involves important *intra*bank as well as *inter*bank issues.

The larger the network, the greater the benefit to the consumer of joining the network. So anticipating the consumer rush to the emergent standard service network, banks are precariously perched between advancing their proprietary positions (while solving the difficult integration problems that the continuous upgrading of legacy IT systems requires) and building a more open, interoperable, secure, and reliable electronic banking infrastructure that will promote consumer confidence and greater usage.

Standard drawbacks to such an environment are underinvestment in experimentation and the rush by consumers to the standard solution rather than to the best solution. (OECD, 1991) For example, some bank industry representatives worry that not enough experimentation is taking place or that commercial financial software (such as Quicken or Intuit) may be emerging standards for customer-financial service provider interface. Yet these software products are far from achieving the "user friendly" attributes that banks feel will be needed to bring the majority of the consuming population into the orbit of electronic banking. Moreover, such proprietary software is not necessarily in the competitive interest of banks as providers of financial services access and may lead the way to technology companies entering the financial services market as direct competitors to banks. (Economist, 1996)

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[71] Economists distinguish between physical and metaphorical networks in their analysis of network externalities. Banks have long had attributes of both. The back-office to front-office relationship between the main office and its branches is maintained through a physical network while the relationship between the branch (or ATM) has been a metaphorical network. The concept of the networked bank appears to be moving in the direction of a thoroughly physical network requiring the electronic transfer of information throughout the value-added chain from financial service providers, and their suppliers, to the households of final consumers (equipped with screen phones, personal computers, and set-top boxes).

Banks are increasingly sensitive to the uncertainties of what the consumer will choose. The stakes of the wrong choice are high. On the one hand, every bank wants to become the standard service provider, or at least part of the dominant network of financial service providers. On the other hand, if investments are made in one direction and the consumer moves in a different direction, the previous investment — and time — is lost and the switching costs can be enormous.

The basic problem is that there are so many choices emerging for consumers of financial services, and so many technology application paths for banks to follow, that they are reluctant to "bet the company" on one direction or another. Of course, at the same time, they must move forward technologically, waiting for consumer preferences to clarify.

In Chapter 8 the nature and scale of barriers to IT investment in banking will be considered along with those in the other case study industries. This allows for a more complete picture of service sector market failures and the appropriate policy response.

6. CASE STUDY: BARRIERS IN TECHNOLOGY DEVELOPMENT AND IMPLEMENTATION IN THE HOME ENTERTAINMENT INDUSTRY

6.1 THE SIGNIFICANCE OF THE HOME ENTERTAINMENT SECTOR

However it is defined, the home entertainment industry is very large, economically and culturally influential, and a major user of technology.[72] For the most obvious core of the home entertainment industry — radio, television and motion pictures — over the decade from 1984 to 1993, growth rates in employment were 55 percent for radio and television and 87 percent for motion pictures. Employment in radio and television and in motion pictures represents somewhat more than 1 percent of the employment in the private service sector. As we explain below, technological convergence across communications industries, publishing, movie making, and computing suggests a somewhat broader definition, and hence somewhat more employment, for the home entertainment industry.

Employment and sales statistics alone fail to capture the cultural significance of this segment of the economy. For decades, the television has served as the American household's conduit to the outside world**.** For 50 years the home entertainment and information experience has been shaped by television programming. From Howdy Doody Time to the Muppets to Michael Jordan; from the civil rights marches in the U.S. South to Tiananmen Square; from Vietnam to the night raids on Baghdad, television has had a pervasive influence on American (and worldwide) culture, consumer preferences, and perceptions.

In the home entertainment industry, the use of IT entails the investments made by households in technology such as televisions and computers, by the cable television and satellite communications industries, by the television industry, the movie industry, and in telecommunications industry in general. Industrial statistics for 1992 alone, show the combined IT investments for motion pictures (SIC 78) and

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[72] The rapid convergence of various forms of communications, entertainment, and computing technologies leaves the definition of the "home entertainment" sector somewhat indeterminate. We shall employ a very broad working definition of the home entertainment industry as including SIC 4833 (terrestrial broadcasting); SIC 4841(cable television); SIC 4899 (satellite communications); SIC 4812 (cellular/PCS); SIC 7812 (movie production) and SIC 2711 (news production, newspapers). How much one aggregates to reach a definition of a home entertainment industry is of course somewhat subjective. Certainly one would start with SIC 4833 and SIC 4841 and then add the "traditional" content of SIC 7812. Then, one could maintain that because of convergence it makes sense to add SIC 4899 and SIC 4812 and some fraction of the telecommunications/telephone industry. Then, with advances in computer technology, it becomes increasingly possible to access the content of newspapers on line and all the major papers and magazines are indeed providing "cyber editions," so adding a portion of the publishing industry is also supportable.

radio and television (SIC 483 + 484) to be approximately $4.87 billion, $1.37 billion and $3.50 billion respectively.

But the technological support for the home entertainment and information experience is changing rapidly, converging with telephone communications, with computer technology, and with networking technology. These technological changes could have profound effects on the structure of the entertainment services sector and the nation's cultural experience.

6.2 THE NATURE OF HOME ENTERTAINMENT TODAY

The "home entertainment" industry, like many services industries, is being transformed by the IT revolution. To understand this transformation requires that we consider not only the devices with which consumers receive electronic information and entertainment service "content," but also the variety of distributional modes by which the content is delivered.

The initial focus of this case was "television entertainment." It quickly became obvious that this distinction was untenable. Televisions and computers — two very different technologies — are today vying for a position as the centerpiece of home entertainment in the future. To refer to television entertainment is too narrow a focus. Industry representatives see two somewhat different technology scenarios following independent development tracks and merging at various points along the way.

A traditional distinction between these two technologies and industries — one delivered entertainment, the other information — has become increasingly blurry, and will become moreso in the future.

Between the content provider and the home receiver equipment, be it computer, television, or some hybrid device, are four basic video signal broadcast modalities: i) terrestrial — a transmission tower on the ground sends a picture directly to a television antenna ; ii) coaxial or fiber optical cable — television signals travel through an underground cable; iii) microwave — a multi-channel, multipoint distribution system carries signals from a television studio to a microwave transmitter and then to rooftop receivers; and iv) satellite — a broadcaster uplinks a signal to a transponder on a satellite, which re-transmits to a receiver dish.

In the following section we will discuss how the development and implementation of IT is affecting the competitive nature of the many industries that are integral to the production and delivery of home entertainment. The essential dynamic is one of technological and industrial convergence. Content providers have merged with cable companies; traditional broadcast companies have merged with major content providers, and are increasingly looking for involvement in cable transmission and the Internet; cable broadcasting and telephone companies are angling to serve each other's traditional markets for cable programming, on the one hand, and telephone service on the other.

The market turmoil that this convergence generates — and the implications for generating uncertainty that may lead to underinvestment — is succinctly summarized in what one analyst calls the Negroponte Switch: "What currently goes by air, chiefly broadcast video, will soon switch to wires (fiber optics and coaxial cable), while what currently goes by wires, chiefly voice telephony, will massively move to the air."[73] Industries that have been the mainstay of home entertainment for decades are giving ground to industries rooted in alternative digital technologies; and industries that we have long thought of as distinct are merging together to provide multiple information and entertainment services. "In the long term," according to one account, "the distinction between long-distance carriers, telephone companies, cellular service companies, satellite services, cable television providers, and other communications and electronics industries will become blurred. Companies in different industries will merge, or form partnerships, resulting in a 'high-tech stew' of interactive communications services that handle voice, data, and video." (Gale Research, 1994)

Figure 6-1 shows the value chain relationship among selected service sector industries being affected by this convergence.

Several burgeoning services appear to be the common objective of these converging industries:

- Support for digital television (HDTV, 500 channels, interactive television, video-on-demand, home shopping, games)

[73] Nicholas Negroponte is Director of MIT's Media Laboratory. Gilder (1994) asserts that Negroponte's formula "brilliantly captures the key vectors of change" regarding the industrial and technological transformations stimulated by the digital revolution.

- Support for video game systems and multimedia CD players (games, linking game players via telephone lines)

- Support for on-line games and entertainment services (games, bulletin boards and chat services, on-line shopping, the World Wide Web)

- Support for digital audio systems (on-line digital music distribution, interactive music, home digital audio recording)

- Other emerging services: video telephones, digital film and video processing, digital art. (Kinney, 1995)

Figure 6-1. The Convergence Value Chain [74]

Content Origination	Packaging & Navigation	Transport & Delivery	Customer Equipment
Books	Publishers	Terrrestrial Broadcast	Multimedia PCs
Newspapers	TV/Cable Programmers	Cable TV Franchises	Televisions
Magazines	TV/Networks	Telephone Networks	Set Top Boxes
Software	Film Studios	Satellite Networks	CD Players
Movies	Computer Operating Systems	Transportation Businesses	PDAs (Personal Digital Assistants)
Online Information	Online Service Providers	Bank Branches	Video Game Players
Financial Products /Services	Financial Advisors		Screenphones
			ATMs (Automated Teller Machines)

To some degree the following service industries are, or intend to be, involved in the provision of entertainment and information to the home: terrestrial broadcasting; cable television; satellite communications; telecommunications; cellular/PCS; movie production; newspapers; and magazines. While historically distinct, many believe that in the years ahead their distinctiveness will fade. After briefly reviewing industrial and technological trends in each of these industries, we will highlight the key technology areas and the barriers to their timely development and implementation as identified by industry representatives.[75]

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[74] Source: (Bank Administration Institute/Boston Consulting Group, 1995)

[75] Unless otherwise indicated, the following industry overviews are drawn from (Gale Research, 1994) and from interviews with industry representatives, including ABC, CBS, NBC, CNN, Time Warner Cable, and The Walt Disney Company.

6.2.1 Terrestrial Broadcasting

The television broadcasting industry is a study in convergence, the process by which hitherto separate industries — broadcasting, information and entertainment content, telecommunications and computers — merge into a single industry. (Laven, 1996) There appears to be a general consensus that convergence of the traditional broadcasting industry is occurring, but the shape the industry will take is still quite uncertain. Evidence of industrial convergence brought about by the IT revolution can be seen in the alliance of Microsoft Corporation and NBC to produce MSNBC, a Web-based news site, and by Walt Disney's acquisition of ABC, to name just two illustrative developments.

From the time TV came into widespread use through the 1960s, home entertainment was more or less synonymous with the large TV broadcast networks — ABC, NBC, and CBS. But the IT revolution — the development of new technologies to handle digital video — is transforming TV entertainment into a "high-tech stew" combining traditional broadcast technology with cable television, interactive media, and satellite technology as new modes of entertainment content distribution. Traditional TV broadcasting faces an uncertain future, certainly a more complex future, and is part of a great industrial and technological reshuffling that is one manifestation of the IT revolution. For the generations of Americans growing up in the 1950s through the 1980s, it is difficult to imagine a home where the television is not one of the central conduits to the outside world. Today 98 percent of US households own TV receivers (67 percent own 2 or more); 63 percent of TV households receive 30 or more channels; and for 70 percent of the U.S. public, television is the main source of news. (National Association of Broadcasters, 1997) And yet, the potential scope of the technological and industrial convergence that is underway in the home entertainment industry is succinctly grasped in the vision of one technology futurist as a "life after television."[76]

While regulatory issues, *per se*, are beyond the scope of this case study, the regulatory environment does significantly shape the supply and demand for entertainment services. In fact, changes in U.S.

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[76] "Life After Television" is the title of a book by highly regarded technology futurist George Gilder. (Gilder, 1994) Gilder develops the logic of industrial transformation that follows from the explosive growth in bandwidth made possible by fiber optic technology; the continuation or Moore's law in microelectronics technology; and the power of distributed computing enabled by the Internet. Gilder foresees an industrial morphology marked by the death of telephone and television technology, and of the industries that support them, and of the rise of the "teleputer"-- a home entertainment/information receiver based on the progressive scan technology of the computer screen rather than the interlace technology of the television picture tube. The "entertainment" industry that reaches the home through Gilder's teleputer is structured like today's book and magazine industries -- multiple niche-oriented content providers (of video and print) -- rather than today's entertainment industry with its entertainment megaliths (such as Time Warner or Disney). All this varied "content" is

telecommunications laws have played an important role in transforming the identity of what were for years the giants of the television broadcasting industry. Anticipation of these changes was instrumental in Disney's acquisition of Capital Cities/ABC, Westinghouse's takeover of CBS, and Time Warner's purchase of Turner Broadcasting. (Council on Competitiveness, 1995)

In addition to competition from cable and direct broadcast satellite service providers over a decade, the traditional broadcasting firms have faced competition from new terrestrial broadcasters as well. Fox Broadcasting has become a significant presence over the period of a decade and in 1994 lured a large number of stations away from the traditional rivals. Its capture of the rights to NFL broadcasts (from CBS) signaled to some a fundamental shift in the network "picking order." Over and above its competitive struggle with rival entertainment delivery modalities, some in the terrestrial broadcasting industry feel that the industry is playing an ineffective role in technological matters affecting key technology suppliers. In part because the manufacturing base for much electronic equipment has moved offshore and in part because new entrants into the broadcast world bring a different industrial culture (shorter product cycles), representation from content providers and broadcasters is perceived to be weak. According to the British Broadcasting Corporation's Laven,

> The 'new entrants' to the broadcasting field, such as telecommunications operators and computer manufacturers, are very active in promoting their technologies and standards. This is apparent in the meetings of DAVIC (Digital Audio Visual Council), an organization that has been set up to develop specifications on a world-wide basis for emerging audio-visual applications and services, such as video-on-demand. Although DAVIC is clearly addressing the future of broadcasting, few of the active participants are content providers, and even fewer are broadcasters. (Laven, 1996)

According to industry representatives, broadcasters are bolstering their core broadcasting business by developing the interactive "back channel" technology (the capability of the viewer to communicate back to the broadcaster) while at the same time they are diversifying into "a far more interactive experience" that is Internet-oriented and interfaces with more computer-like in-home equipment. Broadcast industry representatives foresee what is today largely two distinct in-home equipment interfaces — one with the television and one with the computer, typically in different rooms — merging into a single in-home device that allows the user to view broadcast news and cable television programming and also conduct banking

delivered ("narrowcasted" in Gilder's terminology) to a viewing audience, that could be as small as one, over the Internet.

transactions and e-mail. This transformation is expected to occur over a ten-year period. A consistent theme in industry interviews was the importance of digital compression technologies.

Broadcasters are also upgrading their “back-office” IT. An essential operational function is the tracking and billing for programming to affiliate local stations. IT is being implemented to achieve electronic payment and imaging, to simplify billing, to incorporate full-motion video for advertising, and, of course as software upgrades to achieve multitasking capabilities.

Finally, broadcasters have large stocks of analog film. As re-runs and vintage movies are a major source of programming revenue, considerable investment is being made to “digitize” that film stock to make it compatible with an increasingly digital infrastructure.

6.2.2 Cable Television

Cable television was developed in the 1940s to serve small communities unable to receive conventional television signals. In the 1950s, cable only served 14,000 subscribers. By the early 1990s, cable systems were serving 62 million subscribers and a distinct industry of “cable broadcasters” (whose major or sole market was cable broadcast systems) had developed. The average cable system provides some 30-50 channels.

The cable television industry is maturing. Demand for basic cable service has essentially reached its limit, and future industry growth is expected to derive from new services and expanded channel availability, rather than from growth in the customer base.

With the upgrading of cable systems to incorporate new technology, such as fiber optics and interactive capabilities, cable television firms are planning to expand their services offerings (e.g., expanding to the legendary “500 channels”) and enter the once separate world of telecommunications. The ongoing upgrading of cable television’s infrastructure to fiber optic cable will expand channel capacity and improve the capacity to carry voice, data, and video simultaneously while improving interactivity between the programming service providers and their customers.

Optical fiber technology offers immense data carrying capacity. Data rates of 2 gigabits per second and higher may be achieved using this medium. This kind of data transmission capacity can transmit the equivalent of 750,000 pages of text (stored on a CD-ROM) in under a second, or 1,200 channels of digitally compressed broadcast-quality television. Cable TV companies have converted much of their transmission infrastructure to optical fiber and plan to deliver digital video to the home in this mode. (Kinney, 1995)

The cable television and telecommunications industries are still highly regulated. While regulatory issues are beyond the scope of our case study investigation, regulatory developments can affect the demand and supply of cable television services and telecommunications services. (Both industries increasingly utilize fiber optical cable as a transmission medium but have long been prevented from carrying each other's service. According to cable industry representatives, the wall of separation is beginning to come down with local and regional experiments allowing cable television firms to carry telecommunications traffic and telecommunications firms to carry cable television traffic.) In any event, leading telecommunications, cable television, computer and software manufacturing firms, and even utilities, are positioning themselves to provide information and entertainment services as regulatory restrictions ease.

Leading cable service firms are engaging in a wide variety of strategic alliances to achieve capabilities across the technological spectrum, from telecommunications, to information and entertainment content, to the Internet. Their focus for the near future appears to be the provision of more channels, interactive media and cable modem technology. Underlying many of these efforts is a commitment to the development and implementation of next generation digital compression technologies. For news-oriented cable organizations, there is considerable interest in low-earth orbital satellite technology. This technology is believed to be capable of transforming news gathering and transmission to provide "on-the-scene" coverage of news events more easily and cheaply than current technologies permit.

The core business of cable service providers is the integration of broadcast, satellite, and cable signals; the insertion of commercial advertising content; and the distribution of cable signals to end-users. A primary technical concern is to perform the integration and distribution as fast as possible. To that end, cable companies are investing in high-speed network technologies and high-speed data servers. Because the home computer is growing in popularity, the incorporation of cable modem services is a key object. The cable industry representatives, like their terrestrial broadcasting counterparts, are focused on providing service to their core customer base of cable viewers and diversifying to meet the growing demands of the computer-equipped home. Industry representative are confident that for the near future they will position themselves to serve three relatively distinct populations: TV-only; computer-only; and both. According to one cable industry technology officer, "It's not like 100 million viewers are going to just pick a single modality."

6.2.3 Satellite Communications

From its inception in the 1960s, the satellite communications industry was dominated by government agencies, the military, and international organizations. In the last decade or so, new technologies and trends toward privatization have resulted in new commercial applications of satellite technology.

New satellite television broadcast technologies utilize higher frequencies than the traditional C-band frequencies. Combined with the positioning of the satellites, new technologies (referred to as Direct Broadcast Satellites (DBS)) utilize advanced digital compression technologies to expand the anticipated number of channels available to consumers. Total anticipated capacity is between 128 and 256 channels. The first national digital television service will likely rely on these advanced technologies. (Kinney, 1994)

As a transmission technology, satellites compete with, and complement, fiber optic technology because both transmit digital data. It is expected that over time the cost of transmitting data via satellite will fall close to that of cable. And as in the cable television industry, digital compression technologies are being developed and implemented to compress multiple programs onto a single channel, driving down the program transmission costs.

A new generation of satellites was launched in the early 1990s. The new satellites contain twice as many transponders as the preceding generations of satellites and with compression technologies each transponder is capable of carrying several channels of video. It is these transponders which are leased or owned by television and radio networks and cable companies. Satellite services are provided by a handful of major operators whose revenues come largely from video transmissions for news feed services, cable television networks, and terrestrial broadcast networks.

6.2.4 Cellular/Personal Communications Services (PCS)

The telecommunications industry is somewhat peripheral to our focus on home entertainment. However, these more or less distinct sectors are growing together technologically and in terms of customers and the services they provide. PCS is envisioned by cable broadcasters as an alternative to gaining physical access to the home over local telephone wires. It has been suggested that PCS represents an early manifestation of the fully integrated digital home service industry. (Gale Research, 1994)

Telephone paging and beeper services have become familiar in many occupations. For some industries, such as sales and medical services, they have significantly changed peoples' day-to-day practices. The cellular phone industry is of very recent origin, the first cellular system being installed only in 1979. Cellular services grew rapidly in the late 1980s and into the 1990s. In 1993, 14 million subscribers produced revenues of some $10 billion.

Most standard cellular systems use analog technology, although many are being converted to digital. Increasingly, personal communication services (PCS) provide an alternative to conventional cellular systems. PCS utilizes digital technology to deliver greater sound quality, and promises the more efficient use of limited (publicly regulated) radio frequencies. Cable companies plan to use PCS technology to convert their networks (designed primarily for one-way communication from the station to the user) into two-way communications channels that could deliver telephone services, interactive data, and video. PCS could also be used by cable television companies and long-distance carriers to bypass local and regional telephone lines.

Several initiatives are underway for global satellite communications networks that would vastly expand the reach of terrestrial PCS and could eventually allow satellite systems to dominate global communications. For example, Motorola's Iridium project would allow customers to call or be called (phone, fax, or page) anywhere on earth, any time, using hand held wireless telephones. As well, a consortium of more than 150 local telephone, cellular, cable television, and utility companies was initiated by MCI to build a nationwide PCS network. Other industry leaders include GTE, AT&T Wireless (formerly McCaw Cellular, the nation's largest provider of cellular telecommunications in the early 1990s), BellSouth, Southwestern Bell, Bell Atlantic, and NYNEX to name a few.

"Content" providers too are looking to be involved with PCS. For example, a few years ago, *The Washington Post* took a strong equity position in American Personal Communications, a PCS start-up, and Time Warner entered into a strategic alliance with U.S. West to engage in PCS trials. Of course, computer manufacturers are designing and producing PCS-related equipment.

Arguably, PCS represents an early manifestation of the technological dynamic underlying the convergence of the home entertainment and telecommunications sectors. Besides allowing cellular users to utilize the same phone number for wireless and land line communications devices, PCS promises to deliver data transmissions as well. PCS technology may be used to deliver video services or allow highly mobile employees (such as a sales force) to tap into office computers and FAX machines. Summarizing the potential role of this technology, one observer notes: “wireless telecommunications will transform the prevailing paradigm of human interaction.” (Gale Research, 1994)

6.2.5 Telephone Communications

Like cellular communications technology, the telephone communications industry is somewhat peripheral to our home entertainment focus. However, like PCS, it is relevant because of the convergence of industries and technologies noted elsewhere. To the extent that today’s networked home computer is competing with television as the home’s interface to the outside world, the delivery infrastructure is primarily telephonic. The traditional, or “wire line,” telephone communications industry includes firms that provide electronic communications over networks of wires or fiber optic lines. Into the mid-1990s, the industry was characterized by continued deregulation, increasing competition, an emphasis on data communication and digital technology, and globalization. The distinctions between long-distance carriers, local telephone companies, cellular service companies, satellite services, cable television providers, and other communications and electronics industries are becoming increasing blurred.

Most telephone networks transmit voice and data using analog technology, which sends sound waves over the phone line. In the early 1990s, only about 50 percent of the local telephone service providers (Bell Operating Companies, or “Baby Bells”) were served by digital central offices and only a fraction of those lines were equipped to handle digital integrated services digital network (ISDN) technology. This technology enables the local telephone operating companies to more fully utilize the vast installed base of local copper wire (designed to transmit analog signals) to transmit digital data much more rapidly than would otherwise be possible. The expansion of ISDN digital services, once thought to be a very promising solution to the constraints of analog telephone technology, has been considerably slowed by upheaval in the telecommunications industry caused by the divestiture of AT&T’s Bell telephone system, regulatory prohibitions of all sorts, and very effective competition from rival technologies. (Marx, 1994) In the mid-1990s, local wire line services providers were investing heavily in these rival cable and wireless service capabilities.

6.2.6 Motion Picture and Video Tape Production

As discussed in Section 6.2, the emerging “home entertainment industry” has two roots, one in entertainment and one in information. At the base of one spur in the home entertainment value chain is motion picture “content:” the production of stories and their presentation through acting or animation.

Of course movie production precedes the television age, dating from the turn of the century through the 1920s through 1940s, it was the dominant entertainment medium in the U.S. — and played an important part in exporting American culture and values throughout the world. The rise of television dampened the demand for movie theater offerings throughout the late 1940s and 1950s. Meanwhile, established movie companies, such as Columbia, Walt Disney, and MGM, created telefilm production subsidiaries. Independent production companies — such as DesiLu Productions — were established specifically to produce television programming. By 1963, almost 70 percent of prime-time television programming was produced in Hollywood.

A revolution in television and film production took place in the early 1980s as new television technologies became commonplace. Videocassette recorders, cable television, and satellite broadcasting led to an increasing demand for entertainment content — and fundamentally changed the economics of movie production. Revenues from motion picture production today are distributed thus: approximately 35 percent from theater box offices; 25 percent from television; and the remainder from videocassettes.

Conglomerate mergers have resulted in vertically integrated firms that control entertainment and information content production and a range of distribution modalities. Time Warner, for example, controls both movie (Warner Brothers Studios) and news (Time Inc.) content and a number of distribution modalities including cable services and movie theaters. By the same token, Walt Disney is a leading producer of entertainment content and controls important delivery capabilities such as ABC, ESPN, the Disney (cable) channel, and several hundred trade periodicals.

IT is dramatically affecting the production as well as the delivery of movie content. The television and the computer serve as the final interface between content producer and final consumer of entertainment services. Increasingly, the content provider is also affected by a digital interface. That is, digital technology is transforming the supply side of content as well as the demand side. For example, industry representatives describe the digitization of movie production, beginning in the early 1990s. While the popular movie "Toy Story" is recognized as a wonder of digital technology, end-to-end digital was pioneered much earlier, in the Rescuers Down Under" movie.

The lengthy process of casting is also being affected by IT as video data bases are used to pare down the time and expense of casting "cattle calls." New systems provide digitized portfolios of video auditions to the desktop of casting professionals that perform additional sorts, depending on the casting criteria. (Amdahl, 1995)

Industry representatives describe video compression technologies, digital television, antenna design, analog film digitization, and next-generation compact disk technologies as important areas of technological concern. Like others in the home entertainment value chain, movie industry representatives foresee personal computers in the home as a wave of the future and are interested in "developing navigational schemes (user interfaces) that appeal to the public's sense of exploration."

For the longer term, entertainment content producers are interested in developing "tools" that allow creative people to better express themselves in a new digital medium. The industry is puzzling over the uncertain institutional base for developing such talent. While there are numerous film production schools, they say, there are fewer institutionalized sources of "story telling" talent equipped with the knowledge of what is required to appeal to the public's sense of exploration in a digital age.

6.2.7 Newspaper Publishing

As a daily source of political, economic, and cultural "information content" the newspaper publishing industry has long had a special role in our society.[77] Yet the print media has been locked in a protracted competitive struggle with the broadcast industry, and more recently the cable news industry, for decades. The full embrace of IT by newspapers may have significant competitive ramifications.

While newspapers compete among themselves in local areas, their major rivals are other producers of information services. Increasingly, newspapers are merging with communications companies. From 1960-1990, newspapers were fundamentally transformed from large family-run companies to components of large multi-media companies:

> By 1989, Washington Post, Times-Mirror, New York Times, Gannett, and Knight-Ridder combined were responsible for approximately one fourth of the newspapers read each day in the United States. (Gale Research, 1994)

[77] In the words of Supreme Court Justices Hugo Black and William Douglas, (*New York Times* vs. United States, 1971): "In the first amendment, the Founding Fathers gave the press the essential protection it must have to fulfill its role in our democracy." (Irons and Guitton, 1993)

By linking the newspapers in distant cities, the corporations that controlled them produced a standardization of content and style. These corporations began to branch out into related industries, such as book publishing and marketing. With time, then, newspapers have become components of communication systems rather than the independent, self-contained entities that they have long been. To some extent these trend toward concentration and standardization appear to move in an opposite direction of the current trend toward personalization being enabled by new forms of IT.

In the mid 1990s newspapers are becoming electronic information suppliers, with optional electronic editions fast becoming the norm. With the rise of the Internet, many of the integrating and intermediate content control functions performed today by telecommunications companies, broadcasters, and cable firms can be performed by the end user. Some experts believe that this technological evolution puts increased emphasis on the development of content, and that, in fact, the content industry itself will undergo profound structural change over time because content providers (individual analysts, writers and artists) can now have a direct connection — through the Internet — to end users. (Roberts, 1995) MIT Media Lab Director Nicholas Negroponte envisions “The Daily Me” — a personalized paper filtered from the floods of information by agents programmed to pursue individualized interests. Today, a company called Flat Panel produces a “display tablet” or “newspanel” (a portable tablet with laser printer resolution and hundred of megabits of solid state or hard disk memory) that Gilder calls, “a token of a technology that will sweep the world.” (Gilder, 1994)

The age of electronic text, experts observe, depends entirely on the development of screens with the definition of a laser printer (some 200 to 300 dots per inch). While this is regarded as overkill for images, screens of this resolution could provide the first display tablets with screens as readable as papers. The delivery of electronic news — without the centralized manufacturing and printing cost or the distribution costs — could be 50% of current cost. (Gilder, 1994)

6.3 MAJOR COMPETITIVE ISSUES

This section describes the major competitive issues facing home entertainment industries today. Many of these issues were introduced in the previous section. It is noteworthy that virtually every significant competitive issue mentioned in the entertainment industry literature and in industry interviews has an important technological component. The single most important competitive issue for the home entertainment industry is a persistent theme in the preceding section: strategic posturing for technological and industrial convergence. It appears that firms are positioning themselves horizontally (in all the delivery modalities — broadcast, satellite, cable, and the Internet) as well as vertically (from content to delivery), through mergers and alliances to take advantage of the bandwidth that is increasingly available.

Certainly from the perspective of those who deliver content to the home — terrestrial broadcasters, cable firms, satellite transmission services, Internet providers — competition for advertising dollars is among the most important competitive issues. But underlying this is a deeper technological issue: the expansion of bandwidth; the substitution of regulated bandwidth scarcity to a cornucopia of bandwidth brought about primarily by the shift to fiber optic cable and technologies — like digital compression or ISDN— that effectively increase the bandwidth (signal carrying capacity) of the existing infrastructure.

Also, industry representatives uniformly report uncertainties in coming to terms with the potential of the Internet. Maintaining the proper strategic balance among the delivery modalities is crucial to home entertainment firms. Based on a number of interviews with senior technology officers across the home entertainment industry, it appears that they are moving rapidly in the direction of developing and refining Internet capabilities.

Regulatory issues are also critically important to the industry. Many regulatory issues have important technological dimensions. For example, in November of 1996 the Federal Communications Commission announced a digital television standards agreement among television broadcasters, manufacturers, and the computer industry that would enable them to "start planning huge new worlds and uses of TV in a digital world." (Platt, 1997) The agreement adopts 18 digital TV format standards, some of which are incompatible with the requirements of computer technology. (Platt, 1997; Ness, 1996) Reportedly, this agreement is the first in a series of FCC determinations concerning digital television. The standards-making processes that led to the 1996 agreement produced friction between television broadcasters and television equipment manufacturers, on the one hand, and computer manufacturers on the other. The conflict is essentially one between the two technology scenarios (a computer-centered, "progressive scan" technology on the one hand, and a television-centered, "interlace technology" on the other) discussed throughout the preceding section.[78] It has been observed that interlace technology poses

[78] Interlace technology is bandwidth-saving technology. An interlaced system transmits odd-numbered scan lines to a TV tube in one sweep, then even-numbered scan lines in the next sweep so that only half the picture needs to be sent at a time.

serious problems for viewing text and multimedia. (Gilder, 1994) To the extent that these technology standards indicate sharp differences between markets for entertainment and markets for information, they appear inconsistent with the increasingly converging markets described by industry representatives from across the home entertainment industry.

Finally, interviews with industry representatives uniformly cite standards issues as a primary competitive issue. The most often mentioned standards-oriented organizations are CableLabs, DAVIC, MPEG, and the DVD consortium.[79] As key users of IT, service sector firms seems chiefly concerned with developing widely-applicable standards, anticipatory standards if possible. In addition to their interesting maintaining a broad vendor base, they appear interested in assuring that consumers are free from system compatibility choices where it benefits the consumption of their entertainment and information services. Furthermore, they believe that their leverage as buyers is an important — perhaps decisive — factor in obtaining resolution of the differences among equipment manufacturers vying for market advantage.[80]

6.4 THE R&D FUNCTION IN THE HOME ENTERTAINMENT INDUSTRY

As we have found in other case studies, the R&D function within the entertainment industry is heavily oriented towards “development” and perhaps could be more accurately described as test and evaluation.[81] Even very large multimedia firms reported relatively small R&D staffs, on the order of 15-25

Progressive scan technology, on the other hand, transmits scan lines -- from the top of the screen to the bottom, as with a graphic image displayed on a computer screen -- in an unbroken sequence, creating an entire single frame of a TV/monitor picture.

79 CableLabs (Cable Television Laboratories Inc.) is a research and development consortium of cable television system operators. focused on the assessment, development, and implementation of technologies by cable system operators. DAVIC (Digital Audio Visual Council) is an international organization aimed at promoting the success of digital audio-visual applications and services based on specifications that maximize interoperability across countries and applications. MPEG (Motion Pictures Experts Group) is a group that meets under the auspices of the International Standards Organization to generate standards for digital video and audio compression with emphasis on the definition of a compressed bit stream. The DVD consortium is a group of 10 or so large electronics, television, computer and entertainment companies that have contributed technology, and developed standards and cross-licensing arrangements for the introduction of the next generation of compact disk technology - digital versatile disk technology.

80 With reference to the DVD consortium, one industry representative argued that a “third party” standards negotiator function (implicitly, “like NIST”) would not be effective in such a negotiation. He believed that effective anticipatory agreement among competing manufacturers was only achieved with the real “carrot and stick” and that only the large entertainment industry buyers like Time Warner or Walt Disney were capable of such inducements.

81 This finding is consistent with National Science Foundation (NSF) surveys. Link (1995) reports that firms reporting large expenditures of “development” funds believe that “development” is defined too narrowly by NSF.

direct reports for a Technology Officer, Chief Engineer, or Information Officer of even very large organizations.[82]

Industry representatives suggest that as IT moved from "back-office" functions (where it predominates in television broadcasting and cable services, for example) toward service content and delivery (as is occurring with the incorporation of video servers, and the development of interactive Internet services), the internal staffs required to maintain these services, and the fraction of staff time dedicated to such "front-office" concerns, is likely to grow steadily.

Industry representatives also report that while they do not develop technologies internally, they do exert some leverage on the R&D activities of equipment vendors and are increasingly involved in collaborative technology efforts such as CableLab, the DVD consortium, as well as standards-oriented organizations like MPEG and DAVIC. It is the digitization of otherwise relatively stable technologies (e.g., television, coaxial cable, film production) that is driving both vendor co-development and collaborative endeavors.

Today, much of the entertainment industry's IT investment is concentrated in operations and "back-office" functions. This focus appears to be changing with the expansion of bandwidth (brought about by the move to fiber optical infrastructure and bandwidth-economizing technologies) and the demand for "more interactive experiences." There is every reason to believe that these trends will continue and that the RDT&E functions in the entertainment industry will continue to grow.[83]

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[82] For very large organizations, this number undoubtedly under-reports the number of personnel dedicated to technology development test and evaluation. Some industry representatives reported a committee structure for integrating technological issues across multiple divisions. Nevertheless, only a few of multiple divisions were reported to have significant in-house technology activities and the staffs of these divisions would also be relatively small.

[83] George Gilder (Gilder, 1994) has formulated a rule of thumb analogous to the microelectronics industry's Moore's Law (according to which processing microchip processing power doubles every 18 months). Gilder, and others (Roberts, 1995) put forward a "Law of the Telecosm," for the optoelectronics industry, according to which bandwidth triples every year for the next 25 years. If Gilder's rule of thumb accurately reflects technological trends, growth in the RDT&E function to accommodate improvements in service content and delivery could be rapid.

6.5 THE TECHNOLOGY LANDSCAPE[84]

Throughout the preceding sections we have distinguished two technology scenarios with a third option formed by the progressive merging of the two. In this section we first attempt to better articulate the basis for the two scenarios and to identify industry technology priorities in that context. We then discuss the correspondence between the entertainment industry's technological priorities and ongoing and planned NIST IT programs and activities. In the following section barriers to the realization of progress for selected technologies are discussed and quantitative estimates of the degree of underinvestment caused by these barriers are presented.

The development of new information and entertainment services is predicted to take place along two broad fronts associated with two families of user interface equipment: the television and associated technologies (set-top boxes and multimedia CD players) on the one hand; and information access via a general purpose personal computer on the other hand.

It is widely believed in the entertainment industry that for the foreseeable future computers and entertainment-oriented devices will continue to develop as related but separate digital system families, rather than converging into a single family. Entertainment systems will continue to have image and sound processing capabilities superior to those of the average general-purpose computer system. Entertainment systems makers who do supply support for keyboard input are likely to continue to emphasize joystick or remote control interfaces.

While the merging of the two into "information appliances" or "teleputers" is believed likely, most considered it to be a decade away for the average household. While entertainment-oriented products have adopted many of the features of computers, for the most part they lack the basic capabilities required by computer users, i.e., a keyboard input. Also, conventional wisdom in the consumer electronics industry says that entertainment-oriented products will not sell if they seem too much like computers.

In Table 6-1 the basic characteristics that differentiate the computer user from the entertainment-oriented user are highlighted. Information services targeted for computer-oriented users are expected to emphasize the first set of features by supporting keyboard-based, word-searching for information retrieval

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84 Unless otherwise noted, this section draws heavily from (Kinney, 1994).

and downloading and/or printing of files, and by focusing on text and still images as opposed to video. On-line information service providers while assuming most users will use the dial-up public telephone network at low transmission rates will also employ piggy-backing on new two-way cable systems at rates in the megabits per second range.

Driving the design of services for the entertainment-oriented devices will be a simple interface for the remote control or joystick. This suggests content that can be easily retrieved through menus, maps, diagrams or other visual schemes. To fully utilize powerful sound and graphics capabilities, many information services are likely to incorporate extensive sound, live-action video, and animation. Providers of on-line information services for use with entertainment-oriented devices will need to work closely with device manufacturers and delivery systems operators (cable systems) to ensure compatibility with specific systems.

Underlying these technology scenarios are three important technological trends:

- Digital data transmission systems
- Digital data *compression* techniques
- Multimedia hardware allowing steady *decompression.*

Digital data transmission: Optical fiber technology offers immense data carrying capacity. Data rates of 2 gigabits per second and higher may be achieved using this medium. This kind of data transmission capacity can transmit the equivalent of 750,000 pages of text (stored on a CD-ROM) in under a second, or 1,200 channels of digitally compress broadcast-quality television.

Table 6-1. Entertainment-oriented vs. Information-oriented Technologies

Computer users: • Interaction through a keyboard • Communication with user-specific and varied text strings and commands • Easy access to printer and digital storage media • Many systems do not yet support full motion video • Access to many on-line systems through a telephone modem • If cable operators open up to two-way use via cable modems, computer users will enjoy higher data rates **Entertainment-oriented devices:** • Interactive with computer systems but using relatively simple equipment • No keyboard, rather remote control and joystick • No printers or storage devices • Good image and sound processing capabilities • Interface technologies (i.e., head-mounted virtual displays will become standard, affordable, home-use elements *before* they are widely available for computer systems • While incorporating telecommunications links, these tend to be specialized and proprietary, permitting users to communicate in certain ways

Telephone and cable television companies have converted much of their transmission infrastructure to optical fiber and plan to deliver digital video to the home in this mode.

By comparison, telecommunications technologies such as ISDN (Integrated Services Digital Network) provide a data rate up to 144 Kbps and, more recently, ADSL (Asymmetrical Digital Subscriber Line) can achieve data rates of 1 Mbps over local copper pairs. Satellites are capable of transmitting at rates of 100 Mbps and greater. Conventional TVs require about 1.5 Mbps and HDTV requires something on the order of 20 Mbps.

While optical fiber will play an important part in “the back channel” of a future interactive home entertainment systems, the *delivery* of video to the home will be via coaxial cable, wireless transmission, and telephone wire. The transmission capacity of coaxial is in the 10-500 Mbps range. Satellites and microwave support transmissions in the hundreds of Mbps.

Digital data compression: Compared to text, uncompressed graphic data requires very large computer storage space. If a typical page of text can be stored in a file size of 3 kilobits or less, an uncompressed digital image could easily occupy 10 megabytes.

While it may be possible to distribute uncompressed digital video over optical fiber (due do its tremendous transmission capacity), current technologies (such as cable, local telephone connections, satellites transmissions, and CD-ROMs) do not have sufficient capacity for the task. The industry is, therefore, acutely interested in digital compression technologies. These technologies make it possible to transmit video data via cable, CD-ROM, and satellite connections. Widely discussed digital compression schemes include MPEG-1 and MPEG-2. MPEG-1 is designed to support CD-ROM players. MPEG-2 allows compression of studio quality video. In addition to these nationally endorsed standards, many proprietary compression schemes still compete with these “standards.”

Multimedia hardware for digital decompression: Computer storage and manipulation of multimedia data — combinations of digitized text, sound, and images — is made possible by the incorporation of digital signal processing chips (DSP). While today’s users of word processing programs and on-line information services appear to tolerate periodic slowdowns in response time, such performance would be unacceptable for the satisfactory consumption of video and audio information. DSP technologies are, therefore, central to the “set-top boxes” through which digital television is produced.

These three technological areas support four major forms of burgeoning home entertainment services:

- Digital TV (HDTV, 500 channels, DBS, interactive TV)
- Video games and multimedia CD players
- On-line entertainment services
- Digital audio.

We have discussed two IT scenarios that are part of the conventional wisdom among entertainment industry representatives, as well as a variation that foresees a merger of these two scenarios 5-10 years hence. There is a third scenario emerging, centered on the Internet. In this scenario, computer hardware (memory and processing power) and operating systems (software) become subordinate to a public, fiber optic-based, computer network. The network *becomes* the operating system. Coupled with open and network accessible programming languages, like Java, experts foresee a profound change in the way computers, and the information they command, are used. (Gilder, 1995; Myhrvold, 1995) The value of any network device, they argue, rises exponentially with the increase in the number of other such devices it reaches. According to a proponent of this view:

> The computer hollows out, and you no longer are concerned with its idiosyncrasies, its operating system, its instruction set, even its resident applications. Instead, you can focus on content—on the world rather than on the desktop architecture. If you want to run a helicopter model on your screen, you don't have to worry about whether you have AutoCAD on your hard drive. You can run a video of the helicopter without owning the right decoder, whether Indeo (Intel's standard) or MPEG-4 (designed for portable appliances) or dynamic JPEG. The helicopter flies over the Net with its own executable code. The network is no longer a threatening place. If you want to use a program from Finland, you don't have to worry that it will introduce a malignant virus to your machine.
>
> Your computer will never be the same. No longer will the features of the desktop decide the features of the machine. No longer will the size of your hard drive or the database in your LAN server determine the reach of your information processing. No longer will the programs in your machine determine the functions you can perform. The network is the computer. The computer becomes a peripheral to the Internet and the Web.
>
> Suddenly, the entire world of new software is potentially available to every computer owner. Rather than being restricted to the set of programs you own, you can use any program on the Net, just as now you can tap any information on the Net. You not only have data at your fingertips; you have programs at your fingertips. (Gilder, 1995)

Of course, this view has its skeptics. Like the industry representatives who see two parallel technology scenarios coexisting, rather than merging (because, they argue, the convergent path is too far off in the future), critics point out that this third paradigm is based on the fallacy that high bandwidth communications will be available to everyone in a timely manner. Critics argue that even in 10 years the communications infrastructure will still be comprised of a patchwork of partial solutions: ISDN, cable modems, and ATM networks, rather than a widely available, high bandwidth “superconnection.” (Grove, 1995). Others argue that, technology infrastructure aside, the average consumers will not derive utility from the capabilities that the proponents of the Internet/Web-based paradigm foresee. Consumers don’t buy bandwidth, it is argued, they buy services. What the average user wants is, “access to a broad range of content, packaged and presented in a friendly, useful, engaging manner, priced simply and affordably, with a strong underlying sense of community.” (Case, 1995)

While industry representatives are aware of this emerging new paradigm, in the sense that they are very much focused on the utility of the Internet in providing entertainment services, whether they yet fully comprehend the practical ramifications of this new Internet-based paradigm — indeed, if anyone does — is unclear.[85]

Key technology areas identified in interviews with technology officers of large entertainment-oriented companies are itemized in Table 6-2.

Digital compression technology — specifically, "going beyond MPEG-2" with practical, widely adaptable standards — was perhaps the most consistently discussed area requiring technological advance. Compression technology appears to be important throughout the home entertainment value chain, from the expansion of programming channels through more effective use of limited (though rapidly expanding) bandwidth, to the conversion of large stocks of vintage analog film and the production of next-generation CD-ROMs (DVD technology).

Table 6-2. Key Entertainment Technologies

- Digital content creation
- Digital copyright protection
- Digitization of analog
- High-speed networks for fast down-loading
- In-home (user interface) equipment (PC, TV, DVD)
- Internet improvements (protocol improvements, content management tools, navigational schemes)
- Network management and transaction-basis billing
- Practical digital compression
- Video servers

[85] Interviews with industry representatives were far-ranging and primarily focused on identifying technological areas of concern, barriers to the more complete implementation or development in broad technological areas, and on estimating the magnitude of underinvestment associated with those barriers. Speculations concerning various technology scenarios were not pursued in depth and are, therefore, based on the authors' judgments. While this third Internet/Web-based paradigm was not the specific focus of discussion with industry representatives, proponents of this paradigm (Gilder, 1994, 1995; and Barlow, 1995) believe that it represents a technological shift that challenges the technology strategies — indeed the very existence — of firms focused on interactive television (such as the broadcasting and cable firms interviewed for this case study).

Improvements in user interface equipment are of critical importance to the entertainment industry, especially as this relates to the development and implementation of widely adaptable standards for set top boxes, digital television sets, and hybrid devices that combine features of the computer with features of the television. Interest in these hybrid devices was apparent in several industry interviews.

Cable service operators were particularly concerned about network management, transaction-basis billing, and more effective video servers. As mentioned above, the downstream end of the home entertainment industry is operations-intensive. The shift to new digital technology, and especially the preparation for video-on-demand, appear to be taxing conventional cable and broadcast operations. This shift of the technological "cutting edge" from back-office operations to "front-office" operations is expected to affect the nature of the internal R&D function as it is currently organized. As discussed above, technology managers foresee their staffs growing to accommodate the increased demands for IT that impacts service content and delivery.

Digital copyright protection is a pervasive and fundamental concern to the entertainment industry. Simply put, "[w]hen copies multiply, value collapses." (Bethell, 1997) It appears that a whole generation of relatively young and sophisticated personal computer users typically share their computer games as e-mail attachments. Industry observers question what will happen when the memory and bandwidth exist to share any artistic creation in a similar fashion. Industry representatives express similar concerns as they look forward to video-on-demand. "We envision the specter of perfect digital reproductions, of programs down-loaded from a digital TV, showing up on the Internet." As well, encryption technologies are used to secure the services that content distributors provide to their customers. Technological means are becoming available to ensure protection such as digital watermarks (i.e., information embedded in pictures, sounds, and videos that cannot be seen or heard without a special decoder) and encrypted electronic envelops (i.e., secure means of sending data objects to specific recipients). (Kurzweil, 1997) Industry representatives express interest in further development and implementation of these technologies.

In addition to the identification of key technologies, industry representatives indicated which of several areas of information technology were critical to the entertainment industry's future. In Table 6-3, these technologies are ranked in according to the cumulative number of responses by industry representatives. While the number of people surveyed was small, they represent some of the largest firms involved in the home entertainment industry. Their responses provide a good cross section of industry technological concerns. Consistent with the technology policy framework discussed in Chapter 3 (regarding the appropriate policy response to the various types of market failures), it is possible to interpret the ranking of technology areas in terms of requirements for generic and infratechnology support.[86]

Table 6-3. Entertainment Industry IT Priorities by Technology Area and Type[87]

Technology Type	Technology Area	Rank
Generic Technology	Video servers	1
	Set top boxes for interactive TV	1
	System integration	4
	Electronic commerce applications	4
	Distributed databases	4
	Hierarchical mass storage systems	4
	System management	5
	Monitoring and control for large networks	5
	Virtual reality	5
Infratechnology	Firewalls and Internet-based tools	2
	User Interfaces and Information Access	3
	WWW and IPv6 security	3
	Multimedia protocols	4
	Data compression	4
	Compression algorithms	4
	Network scaling	4
	Next-generation Internet protocol	5
	Quality of service for multimedia and real-time applications	5
	Cryptographic standards	5

It appears that many of the priorities of the entertainment sector are shared by the banking sector. We suspect that the emphasis on interacting with the customer — for both entertainment and banking, the focus is "in the home"— is the source of this similarity. Also both sectors appear to be focusing a great deal of attention on the Internet as a tool for communicating and transacting with the customer base. In our

86 The list of technology areas ranked by industry technology managers contained technology areas in which NIST technical specialists felt there was an appropriate role for NIST and in which NIST was engaged in technical activities. The list also contained technology areas that were considered more appropriate to private sector activity and where private sector activities were ongoing. Only technology areas that were considered critical to more than one company are included in the table presented here.

87 Respondents were asked to indicate which of 49 technology activity areas (identified in Perine, 1996) were of critical importance to their industry's future. We emphasize that interviews were informal and that these results are impressionistic. Interviews covered a broad range of topics within a very limited interview period. Technical areas are ranked according to the cumulative number of times they were indicated as critical to the home entertainment industry's

interviews with *entertainment* industry representatives, it was not uncommon for a service scenario to include the idea of the consumer viewing entertainment programming "and doing their banking" on the same computer/television hybrid in-home device.

Home entertainment shares a different set of common technology concerns with the health care industry. These include concerns with Internet protocols and security, multimedia applications, and systems integration and management.

Finally, while it often proved extremely difficult for industry respondents to uncouple and prioritize the five top IT performance characteristics (usability, interoperability, reliability, security, and salability) it was possible to ascertain a ranking on the basis of several interviews. Table 6-4 presents this prioritization. [88]

Table 6-4. Entertainment Industry Ranking of IT Performance Attributes[89]

Characteristic	Rank
Interoperability	1
Usability	2
Reliability	3
Scalability	4
Security	5

The policy significance of our findings concerning technology priorities in the home entertainment industry will be considered in Chapter 8, together with our findings concerning other service industries.

6.6 BARRIERS IN TECHNOLOGY DEVELOPMENT AND IMPLEMENTATION

Based on our analysis thus far of entertainment technology trends, and the framework for understanding market failures and underinvestments developed in Chapter 3, in this section we discuss the sources of risk and the that various market failures issues related to technology development and

future by interview respondents.

88 The rankings presented reflect the average response. With a larger sample, industry differences would probably emerge. For example, security is undoubtedly a more important issue for cable system operators and for movie content providers, than for a terrestrial broadcaster.

89 Respondents were asked to rank these IT performance qualities as 1=most important and 5= the least important. Rankings

implementation that are consistent with the logic of market failures. Where possible, evidence is presented concerning the scale of the underinvestments that these sources of market failure entail.

The technological convergence between once-distinct industries is highly pronounced in the entertainment sector. This convergence produces significant market uncertainties, that go beyond reasonable levels of risk. Where risk implies predictability, uncertainty connotes the inability to predict; the absence of a relevant base of experience from which to make informed judgments. If, as argued here, risks lead to barriers, and barriers lead to underinvestment, then uncertainty leads to a greater degree of underinvestment.

This uncertainty has many facets. For example, the development of informational and entertainment services are based on adaptations of technologies originally developed for other purposes. This clearly makes "the fog" of strategic planning thicker than it might otherwise be for entertainment industry decision-makers. Two cases where such unplanned modifications have led to significant industrial changes are the use of public telephone networks to support on-line databases, and the development of the CD-ROM as an information distribution medium. (Kinney, 1995) Since "learning-by-doing" is widely regarded as fundamental to successful innovation (Dosi, 1988), if current technologies will be employed to provide services for which current experience provides no concrete guide — as suggested by the "Negroponte Switch" (discussed above) — reduced innovativeness is likely to result.

In addition to uncertainties, new applications of current technologies can be slowed by the adaptation process. Analysts note that new information services must often conform, at least initially, to existing constraints in data storage and transmission capacity and user interface characteristics. (Kinney, 1994) Industry representatives refer to a "wild-west phenomenon" when describing the on-line, in-broadcast interactions expected to be important in tomorrow's home viewing experience. This captures the sense of riskiness and uncertainty felt by the management of the entertainment industry today.

The potential for underinvestment due to systems integration and systems competition issues are ever-present in discussions with industry technology executives. At one level, the industry and the consumers it serves are confronting the choice between computer-based and television-based systems.

were averaged for each item so that the lowest average represents the highest priority.

Conflicts between the computer industry and television broadcasters over regulations and standards for digital television reflect this system competition. The inability of the marketplace to readily coordinate layers of technology systems is indicated by cable industry representative's contention that computer manufacturers don't understand the broadcasting industry's needs.

Similarly, the entertainment industry faced system-configuration choices regarding DVD technology and responded through a collective strategy to standardize and share revenues from technology development investments through cross-licensing arrangements. The DVD consortium, discussed above, is described by industry representatives as an anticipatory response on the part of the entertainment content segment of the industry to multiple hardware and software designs. They suggest that without agreement on widely adaptable standards, potential consumers would fear being "stranded" by the incorrect system choice. This "stranding" psychology is commonly associated with network externality problems.

Many industry representatives focused on the investment constraints imposed by lack of faster progress in the area of digital compression technology. Content providers believe that whole new markets await advances in digital compression. They argue that with improved compression technologies, home video movies could contain both digital and analog formats for only 125% of the current cost of analog alone. Underinvestments are arguably substantial. With a target market of 30-35 million copies per release, and a price of $30 per copy, revenues linked to such technological improvements would be in the billions of dollars. Similarly, terrestrial broadcasters foresee advances in data compression leading to the provision of additional programming through the more efficient use of existing satellite transponder capacity.

Internet service providers couple the need for advances in compression technology with Internet protocol improvements. They estimate that in the event of these improvements, demand for Internet content would expand and industry investments would expand 30% per year accordingly.

Some cable operators argue that improvements in video server technology would enable the provision of Video-on-demand services. The investments to accommodate the expansion of such services could increase 2-3 fold according to industry representatives. The increase in VOD services faces numerous barriers, including new transaction-billing schemes and intellectual property protection. Cable industry representatives estimate that if VOD were in place today, they could invest an additional $2 billion per year over a 5-year period.

Finally, at the most basic level of the supply of entertainment content, industry representatives describe the need to create "tools" that enable creative people to better express themselves in a new digital medium. This is regarded as a chief long-term concern. The industry is puzzling over the uncertain institutional base for developing such talent. While there are numerous film production schools, they say, there are fewer institutionalized sources of "story telling" talent equipped with the knowledge of what is required to appeal to the public's sense of exploration in a digital age. From the standpoint of barriers to investment, this reflects a potential high-order systems integration problem, similar in some respects to what economists describe as "complementary market coordination" problems associated with market failures in an underdevelopment context. If the pace of technological and industrial development were not so rapid in the convergent world of the home entertainment industry, this issue might be regarded as sufficiently long-term to presume that market forces would arise to provide an appropriate response. As well, since the institutional source of such talent might be educational institutions, there may be additional reasons to question whether an adequate level of investment could be expected to materialize. After all, the externalities that characterize such "public goods" as education are the chief economic rationale for the heavy subsidies that educational institutions receive.

Both economic logic and empirical estimates from entertainment industry representatives suggest substantial underinvestments due to specific barriers to IT development and implementation. The potential for underinvestments estimated by entertainment industry representatives ranged from 30% to 300%. While the evidence is anecdotal, our case study suggests that specific barriers to IT development and implementation are discernible, and that rough order of magnitude estimates of the scope of the underinvestments can be ascertained.

First, the general uncertainty that plagues convergent industries is readily apparent in the entertainment sector. At a high level of abstraction this uncertainty can be seen in the presence of two or three viable technology paradigms to which industry representatives must address there planning efforts. Over and above this general uncertainty, firms face serious potential vertical systems integration challenges as debates and disagreements surrounding the implementation of digital television strongly testify. As is also the case in the banking sector, the consumers' preferences are increasingly important and unknown.[90]

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[90] When we say that consumer preferences are increasingly important we mean that the increase in the availability of alternative entertainment/information modalities makes the consumer a more effective voice in market outcomes. Another

Also, progress on advanced digital compression technologies and DVD technology are thought to be very important and key standards related initiatives were highlighted. This focus on the role of standards activities is clear evidence of high transactions costs and suggestive of the presence of network externalities that can lead to market failure and underinvestment.

In Chapter 8, the nature and scale of barriers to IT investment in the home entertainment industry will be considered within the context of the barriers confronting the banking and healthcare industries. Considering these barriers together, as representative of the high-tech segment of the service sector, provides the greatest insight for policy purposes.

way of expressing this is to say that the balance of market power is shifting to consumers. This is also a clear theme in the banking industry.

7. CASE STUDY: BARRIERS IN TECHNOLOGY DEVELOPMENT AND IMPLEMENTATION IN THE HEALTH CARE INDUSTRY

7.1 INTRODUCTION

The health care industry, like the retail banking and home entertainment industries, is in the midst of dramatic technological change, and the companies competing in these sectors must face all of the various forms of risk. The chapter will describe the nature and key competitive features of the health care industry, especially as it relates to technological change, and document the barriers in technology that the risks have created.

7.2 THE SIZE AND SIGNIFICANCE OF THE HEALTH CARE SECTOR

The private health care sector grew by 42 percent in the decade ending in 1993, absorbing about 13 percent of the private service sector's employment and about 10 percent of the entire service sector's employment (including government services in the total for employment in services) with somewhat more than 8 million employees in the private health care sector. The Office of Technology Assessment (OTA) provided some statistics about the health care industry, according to which some 10 million Americans were working in health care—about a quarter of those were doing administrative work—and that the health care workforce was growing at an annual rate of 3.9 percent. Up from 5.9 percent of gross domestic product in 1965 to 13.9 percent by 1993, the total expenditures for health care in 1993 were $884.2 billion, with roughly 43 percent paid for by government sources. The federal government paid almost 32 percent of the $884 billion. (U.S. Congress, OTA, 1995)

Like the banking industry, the health care has many suppliers and has been experiencing a trend toward integration. Health care is even more fragmented; instead of suppliers being numbered in the thousands, their number exceeds 1.2 million. “There are more than 1.2 million health care providers—ranging from solo practitioners to 1,000 bed hospitals—and they are often isolated in disparate corporate entities from the more than 3,000 private insurance payers that distribute payments for health care services.” (OTA, 1995, p. 6)

Like the banking and entertainment industries, concentration is increasing; further, much of the concentration in health care will rely on information technology to create systems. “Some . . . fragmentation may be reduced with the current trend toward vertical and horizontal integration of providers and payers into systems that offer the full ‘continuum of care’ to covered populations.” (OTA, 1995, p. 6)

The health care industry is a key part of the economy, and IT is believed to be a way to reconcile the competing goals of cost containment and quality health care. As a recent Council of Competitiveness report (CoC) observes:

> The quality of health care that has been available in the United States and the advances we have made in medical research have been the envy of the world. But U.S. health care costs as a percentage of gross domestic product (GDP) are the highest internationally and rising. Rising costs compete for valuable resources from the economy and curtail our ability to compete successfully in world markets. ...

At the same time, demands on the health care system for additional and higher quality services are rising. Many still do not have access to appropriate care or cannot afford it. And as the population ages, its need for medical care is increasing. (Council on Competitiveness, March 1996, Executive Summary)

IT appears to hold considerable potential to help improve service and reduce cost. The OTA's recent comprehensive report explains the potential and importance for IT as a way to achieve the national goal of ensuring both containment of costs and the quality of health care:

> . . . two key themes are introduced that echo throughout the chapters. These are *cost containment* and *standards development* [italics in original], and they reflect congressional concerns about containing health care costs and enabling administrative simplification.
> (OTA, 1995, p. 11)

OTA estimates the administrative costs of providing health care at between $108 billion and $135.1 billion per year in 1991, or between 12 and 15 percent of the health care bill. Annual savings that could be realized through increased use of information technology in administrative functions are estimated to range from $5 billion to $36 billion. (OTA, 1995, p. 11)

Of course, the foregoing estimates of the potential use of IT to reduce administrative costs of delivering health care, do not address the potential for using IT in the actual content of health services — a 1994 National Research Council (NRC) report and the OTA report emphasize the numerous ways that IT has improved the treatment of the medical problems themselves — and thereby improving quality and perhaps reducing costs of achieving specified objectives. As the NRC report explains, “IT is today an integral part of diagnosis and therapy.” (Quinn, et al., 1994, p. 78)

However, estimates of cost savings that assume rapid adoption of electronic data interchange and high rates of market penetration may be optimistic; health care providers do not appear to be adopting these technologies as rapidly as forecast. The development and adoption of effective standards is regarded as critical:

> Until standards are in place and compliance is widespread, costly activities—such as maintaining multiple formats for health care information, dealing with exceptions, and developing new interface software as new proprietary approaches to managing health information become fashionable—will continue to offset some potential savings of processing health care records and transactions electronically. (OTA, 1995, p. 13)

The new IT will reduce large transactions costs that are incurred as the industry works to cope with exchanging information. As with the banking industry, there are barriers in technology development and implementation that must be reduced if the potential for IT is to be realized.

7.3 THE NATURE OF THE HEALTH CARE INDUSTRY TODAY

The health care industry in the United States is undergoing a dramatic restructuring, brought on primarily by the pressures to contain costs and by technological change that holds out the hope that the containment of costs can be realized while still providing quality health care. According to the OTA:

> Information technologies are transforming the way health care is delivered. Innovations such as computer-based patient records, hospital information systems, computer-based decision support tools, community health information networks, telemedicine, and new ways of distributing health information to consumers are beginning to affect the cost, quality, and accessibility of health care. Changes in the health care delivery system, including the emergence of managed health care and integrated delivery systems, are breaking down the organizational barriers that have stood between care providers, insurers, medical researchers and public health professionals. Old distinctions between clinical health information and administrative health information are gradually eroding as new health care delivery patterns emerge that are supported by, and in some cases reliant on, the widespread use of networked computers and telecommunications. (OTA, 1995, p. iii)

Today, then, we see a U.S. health care industry at a crossroads; synergies between organizational modes and information technologies are dramatically changing the relations among the customers, the health care providers, and the third-party payers, both private and government, who pay for most or all of the health care received by individuals. (Quinn, et al., 1994, p. 76) Indeed, the organizational modes have shifted dramatically over the past two decades, and the shift has occurred in a way that reflects and reinforces the development and implementation of IT to contain costs and yet deliver a high quality service.

The growth of managed health care has been one of the major influences in the health care industry. These organizations use a number of techniques to control access to providers, contain costs, and manage utilization of resources. The number of people enrolled in managed care plans has increased dramatically in the past 20 years, rising to over half of all employees covered by employer group health insurance by 1992. (OTA, 1995, p. 6)

The health care industry has turned to information technology in order to manage the vast amounts of information that must be exchanged between the providers, insurers, medical researchers, and public health professionals. Quinn, *et al.* (National Research Council), 1994, Table 2.7, pp. 76-77) report that the health care industry's annual investment, in constant dollars, in IT hardware increased fourfold over the two decades of the 1970s and the 1980s. The annual investment in 1982 dollars increased from $0.9 billion in 1969 to $3.6 billion in 1989. Over the same period, the National Research Council further estimates that the health care sector's investment in IT capital stock increased from $3.3 billion to $15.7 billion in 1982 dollars. By 1992, in the 2-digit SIC industry Health Services, IT spending was $3,348 million and IT net capital stock was $17,768 million.[91] (Unpublished National Income & Wealth Statistics, BEA, 1994)

The National Research Council emphasized what we believe to be an important and significant difference in the success of IT: in many applications to actual medical problems IT has been enormously successful, whereas use of IT in the business side of the health care industry has been less so. Successful medical applications of IT are numerous: for example, the use of computer controlled beams of radiation to treat cancer, the use of high-speed computing to do computerized scanning and magnetic resonance imaging, and the use of IT to monitor the vital signs of patients.

However, on the whole the application of IT to business operations (“back office”) and record-keeping activities (“front office”) has been slow. The business operations and record-keeping activities in health care today include several activities:

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[91] These figures are not deflated for comparability to the National Research Council's figures, because an appropriate deflator needs to account for the unusually rapid decline in the prices of computing equipment and the dramatic increases in the quality of the new equipment. Certainly the use of a general price index for economy-wide activity would underestimate the gain in the quality of the IT capital stock over the amount of IT available in earlier years. In the foregoing figures, IT is defined as purchases in the following equipment categories: office computing and accounting equipment, communications equipment, scientific and engineering instruments, and photocopying and related equipment. Thus, software is not included.

> By far the most common use of information systems in health care is for billing, accounting, and administrative tasks, which typically include the admission, transfer, and discharge of hospital patients; materials management; and scheduling and management of human and physical resources. (Quinn, et al., 1994, p. 78)

We believe that the observed slowness in those areas reflects the barriers in technology development and implementation that occur when the technology and market specific risks are especially likely to be important. The discrete, relatively narrow medical science applications that can be developed as stand-alone proprietary equipment to be used by a hospital's physicians and staff are far less likely to founder on technological barriers than the integrated systems of technology to be used widely in networks.

7.4 MAJOR COMPETITIVE ISSUES

The health care industry is highly fragmented and this fragmentation, compounding other barriers in technology development and implementation, is making the task of developing and implementing IT a daunting and slow-moving task. As observed earlier, the providers number more than a million, and there are the over 3000 private insurance payers and various third-party payers as well that must interact with customers and providers of health care. Further, a fully effective IT system must integrate providers and insurers with the medical research community, government health care agencies, and public health organizations. The OTA describes a part of the challenge clearly:

> A network of private-sector intermediaries has formed to facilitate the complicated relationships between the various organizations. It is unlikely that any of these entities will be willing to collect or organize data that save money or effort for some other organization, but deliver the intermediary no immediate benefit; systemic savings may be irrelevant in a vertically fractured industry. (OTA, 1995, p. 6)

As we observed earlier, there is a current trend toward vertical and horizontal integration of the various parts of the health care industries. Acquisitions and mergers, joint ventures, and contracts can be used to forge an “integrated delivery system . . . that brings together hospitals, primary care providers, nursing homes, home health care providers, pharmacies, and other services into a single system.” (OTA, 1995, p. 6) The use of such combinations of organizations is often a way to attempt to surmount barriers in technology that cause market failures and underinvestment in technology. (Teece, 1980) The heart of the challenge for the health care industry is the need to develop the substance of the health care product and the organizational modes of its delivery simultaneously with, and in the context of, the development of the new IT. It appears that electronic data interchange is not achieving rapid adoption, in large part because organizational and technological impediments make it likely that widespread digitization will happen only in synergy with the progressive adoption of managed health care practices and development of integrated service delivery systems. (OTA, 1995)

This challenge of systems integration in a historically fragmented industry, facing strong public pressure for cost containment, would exist even if IT did not fundamentally alter the way that health care services are delivered. Yet in the midst of the integration challenges being faced by traditional hospitals and managed health organizations, on-line health care delivery is also emerging. (Hafner, May 27, 1996, pp. 77-78) While still facing impediments arising from authentication and confidentiality issues, the use of the Internet for the delivery of health care is underway as Ferguson (1996) makes clear.

This change has many dimensions. One observer notes the likely impact on-line communications among patients will have on the practice of medicine:

> The whole structure of medicine has been based on the assumption that physicians have the current information and patients don't. The bottom line is, the consumers will have virtually all the information the professionals have. . . . Once people start getting in good communication, you won't be able to play the game in the same way. (Bulkeley, 1995)

The increase in the use of a drug called gabapentin or Neurontin to treat amyotrophic lateral sclerosis provides an example of how on-line communications can affect medical practice. Patients used the internet to share their observations about the success of the drug, and physicians were then asked to prescribe the drug. (Bulkeley, 1996; Gilbert, 1996)[92]

The report of the Council of Competitiveness about the restructuring of the health care industry in the information age summarizes the challenges facing the health care industry as it develops its own Health Information Infrastructure (HII):

> This restructuring to improve quality and service while reducing costs will not succeed without access to more and better information. Health care providers such as physicians, nurses, and other practitioners, along with health care delivery organizations such as hospitals and managed care systems, need access to more complete and better-integrated patient data. Along with payers, they want more consistent data regarding the outcomes of

[92] Other sources of information about the use of the Internet to deliver health care include: Hedrick (1996), Levy and Snider (1996), NPR (1996), and Walker (1996).

> diagnoses and therapies. Payers want more details regarding the performance of different health plans, and citizens need access to information to assist them in staying healthier longer or in more capably managing their illnesses or those of loved ones....

Advanced computing and communications capabilities will permit distant health care providers to "see" patients, whether they are in their homes, in another city, in another state, or perhaps in another country. Practitioners will be able to access patient information wherever it may be located. Researchers will be able to share appropriate data in order to more effectively assess outcomes and ultimately develop more beneficial treatments to keep the population healthy. (Council on Competitiveness, March 1996)

7.5 THE R&D FUNCTION IN HEALTH CARE SERVICES

Health care organizations have been important users of IT, with the uses in diagnosis and treatment as well as with the processing of administrative work and information more generally. Our interviews with the CTOs (Chief Technology Officers) or CIOs (Chief Information Officers) of such organizations reveal that health care firms actively participate in the development of technology. For example, based on our interviews in the health care industry, a RDT&E group at a large health care company would typically do strategic planning, research on emerging technologies, pilot and implementation projects, research on emerging vendors, have a technical laboratory where testing and evaluation are done, and also have some R&D projects. Based on our interviews, such an archetypal RDT&E group has between 15 and 25 people and reports to the company's CIO, and, again based on our interviews with CIOs, about 80% to 100% of the group's efforts are devoted to IT. Typical projects include applied R&D such as developing software for clinical systems or various testing activities such as evaluating alternative hand-held equipment. In addition, health care companies with large hospitals will have longer term R&D projects in medical informatics. These longer term projects concern issues such as imaging research, not things that will be solved in the next 5 years. Shorter-term projects, like tele-radiology, are more typically assigned to the applied RDT&E group which reports to the CIO.

Interviews with technology development managers indicate that, they continue to play an important instigating role as co-developers of technology.[93] One way that health care organizations

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93 For the health care industry, interviews were conducted with the technology managers of UniHealth America, Wisconsin Health Information Network, a collection of holding companies including Lahey-Hitchcock Clinic and Dartmouth Hitchcock

help to “get the ball rolling” is to participate in collaborative ventures to develop software for the health care industry. Thus, the health care companies that we studied reported participation in product design and development . The health care organizations acted as beta test sites and used the experimental products in pilot programs with their own physicians. Health care industry representatives have also collaborated with the manufacturers of IT hardware—for example, a specialized telephone switch used in the health care organization and provided by a foreign firm wanting to break into the U.S. health care market with its product. With both the software and the hardware development, the collaboration is between health care companies and technology firms that want to understand more about health care. They want to get into the market, and they have a concept. The health care organizations help them to develop the product, adopting the technology, serving as a beta site, and providing feedback.

While there are important exceptions, health care companies, like other service sector firms, tend to follow, rather than lead, in the development of technology of all kinds. This problem of being outside the main locus of IT development activity causes some of the uncertainty health care organizations face in formulating their technology strategies. Clearly medical researchers work closely with computer scientists and other IT experts to develop the IT used in diagnosis and therapy. These IT experts are developing technologies that have been used in other scientific applications. However, the bulk of the R&D that is embodied in the technologies applied in services, is done outside of the service industry and embodied in purchased products. If we categorize all IT-related activities as either development or implementation, the bulk of IT-related activities in health care are implementation related.

Our interviews with health care executives suggest that for large health care organizations, between 10% to 20% of IT expenses are for purchased hardware, 10% to 20% are for purchased software, and 10% are for purchased, external, implementation services. Internal development and implementation costs take the remaining 50% to 70% of the budget, and those expenses are weighted toward implementation and T&E activities. For our interview respondents, an average of 40% of all IT expenses in health care go to “back office” functions, with the remaining 60% are going for service content and delivery.

Medical Center, Columbia/HCA, and Humana, Inc.

Again, based on our interviews, health care organizations also do T&E work in collaboration with other organizations, using their experience and ongoing business to assist especially in software product design and development and to provide a beta test site for new products.

Health care companies also do considerable collaborative technology development work, and additionally, there are many collaborative efforts pursuing standards-related activities. Respondents identified many important standardization actions in progress:

> ASTM is working on laboratory standards. HL7 is working on inter-organization communications and inter-system communications within health care. ANSI is working on message structure, claim and payee related information at the payee level, and has adopted HL7 as an ANSI standard. Additional work is ongoing with CPRI (Computer Patient Records Institute), CORBA medical standards, X12 EDI standards, and more generally work on technological standards for open systems and the Internet.

Standards issues can be closely related to the fundamental nature of the industry. For example, one health care technology manager explained that the most important standards problem for health care is with application data standards. Different people call the same thing different names—disease states for example will have many different names, and the lack of standardized language complicates the successful use of IT.

7.6 THE TECHNOLOGY LANDSCAPE

The Office of Technology Assessment (1995) has provided a detailed documentation and assessment of the technological landscape in the health care industry, carefully explaining the role of information technologies in health care and listing and discussing the key information technologies for health care. Our discussion here focuses on technologies regarded as critical to the future of the health care industry and on the barriers that are preventing greater progress.

The technologies currently important to health care organizations, and those technologies expected to be critical in the next five to ten years, show a strong emphasis on efforts to contain costs. There are immense data acquisition, communication, and storage problems to be addressed with IT. According to one health care technology manager, “Our financial services have been automated for decades, so that part of our IT is quite mature. But our clinical systems are still very much paper based. I say we have a ‘sneakernet’ for moving paper. We move 4000 patient [paper] charts a day in one hospital, and that is growing by 26 linear feet a week. Archival policy is ‘forever,’ so there is a big problem here.”

The key problems within the health care organization are *interoperating* across large numbers of organizations—both within a parent organization and across independent organizations (such as the providers and the insurers)—and *containing costs* by figuring out a way to reduce all of the paperwork—that includes patients charts that are passed around in hospitals and it includes writing prescriptions and signing them. Exotic imaging tools and the like are in the works, but our sense is that inter-and-intra-organization-interoperation and paperwork reduction are the critical near-term objectives for the productivity of IT in health care.

Key technology areas identified in interviews with technology officers of large health care companies are itemized in Table 7-1.

Table 7-1. Key Health Care Technologies

- Broadband networking
- Communications infrastructure (ATM)
- Electronic data interchange
- Interoperability technology (integration technologies)
- Messaging middleware
- Networking
- Security technology
- Telemedicine
- Web technology

- Hand-held technology
- Imaging

- Applications development tools (for speedy delivery of information products)
- Modularity of software
- Object oriented programming

- Large distributed database technology
- Knowledge-based systems
- Records redundancy

In addition to the identification of key technologies, industry representatives indicated which of several areas of information technology were critical to the health care industry's future. In Table 7-2, these technologies are ranked according to the cumulative number of responses by industry representatives. While the number of people surveyed was small, they represent some of the largest firms involved in the health care industry; their responses provide a strong cross section of industry technological concerns. Consistent with the technology policy framework developed in Chapter 3 (regarding the appropriate policy response to the various technology barriers), it is possible to interpret the ranking of technology areas in terms of requirements for generic and infratechnology support.[94]

94 The list of technology areas ranked by industry technology managers contained technology areas in which NIST technical specialists felt there was an appropriate role for NIST and in which NIST was engaged in technical activities. The list also contained technology areas that were considered more appropriate to private sector activity and where private sector activities were ongoing. Only technology areas that were considered critical to more than one company are included in the table presented here.

Table 7-2. Health Care Industry IT Priorities by Technology Area and Type[95]

Technology Type	Technology Area	Rank
Generic Technology	Techniques for manipulating unstructured textual information	1
	Visualization methods for access, manipulation, & exchange of complex visual information	1
	Systems management	1
	Image recognition & processing methods	2
	Scaleable parallel systems both tightly coupled & clustered	2
	Design for speech recognition hardware and software	2
	Systems integration	2
	Data management	2
	Electronic commerce applications	2
	Software testing and analysis tools	3
	Open distributed processing	3
Infratechnology	Firewalls and Internet-based tools	1
	WWW and IPv6 security	1
	Internet security policy development and guidance	1
	Network scaling	1
	Advanced authentication technology	2
	Quality of service for multimedia & real-time applications	2
	Data compression	2
	Wireless communication	2
	Cryptographic standards	3
	Conformance tests for cryptographic standards	3
	Vulnerability analysis and testing	3
	Multimedia collaborative computing	3
	Common windowing protocols	3
	Multimedia protocols	3
	Next generation internet protocols	3
	Compression algorithms	3

95 Respondents were asked to indicate which of 49 technology activity areas (identified in Perine, 1996) were of critical importance to their industry's future. We emphasize that the interviews were informal and covered a broad range of topics within a very limited interview period. Technology areas are ranked according to the cumulative number of times they were indicated as critical.

It is noteworthy that health care respondents expressed interest in some technology areas that neither banking nor entertainment industry firms indicated. These include:

- Internet security policy development
- Techniques for manipulating textual information
- Image recognition and processing
- Scaleable parallel systems
- Vulnerability analysis
- Multimedia collaborative computing
- Common windowing protocols
- Multimedia protocols.

This uniqueness may be indicative of specialized technological requirements. It may also be that while they share technological requirements with other industries, one industry is simply ahead of another with respect to the development and implementation of the technology area in question. Without comparable technology roadmaps it is difficult to make such generalizations.

However, there are also many areas of apparent common interest across the case study industries. These include: electronic commerce applications, cryptographic standards, firewalls and Internet-based tools, network scaling, and wireless communication. Health care technology managers also appear to share a subset of interests with the banking industry, on the one hand, and the entertainment industry on the other. Mutual interests with banking include: design for speech recognition, data management, conformance tests for cryptographic standards, and advanced authentication technology. Mutual interests with the home entertainment industry include: WWW and IPv6 security, systems management, systems integration, next generation Internet protocols and quality of service for multimedia & real-time applications. Health care industry representatives expressed little interest in software conformance and performance testing; in modeling, simulations, and mathematical algorithms; or, not surprisingly, the technologies related to “in-home” equipment such as set-top boxes.

Finally, as in other case study industries, it often proved extremely difficult for industry respondents in health care to uncouple and prioritize IT performance characteristics (usability, interoperability, reliability, security, and salability). Nevertheless, it was possible to ascertain a ranking on the basis of several interviews. Table 7-3 presents this prioritization.

Table 7-3. Health Care Industry Ranking of IT Performance Attributes[96]

Characteristic	Rank
Usability	1
Reliability	1
Scalability	2
Interoperability	3
Security	4

7.7 BARRIERS IN TECHNOLOGY DEVELOPMENT AND IMPLEMENTATION

Without exception, health care managers cite traditional barriers in technology development and implementation as principal causes of underinvestment in IT. However, the human relationship between doctor and patient, perhaps unique to health care, further magnifies these barriers and contributes to slow acceptance of IT improvements.

7.7.1 Types of Barriers and Their Impacts

Industry representatives identified several major implementation problems. According to one technology manager, "Our biggest problem is getting our variety of business units to standardize." Other problems identified included the difficulties of installation and the costs of installation. The chief opportunity cost of addressing these implementation problems is that operating units have to commit resources to set standards and to provide training. The opportunity cost is that it takes time away from providing health care services. For another respondent, "The biggest problem is that implementation is a multi-year process. This is hard for users to accept and understand. We need to pour the right foundation, but users expect everything to happen at once. We need infrastructure and that takes time to build. We have weak parent companies and strong operating units, so there are interoperability problems that exist because

[96] Respondents were asked to rank these IT performance qualities as 1= most important and 5 = the least important. Rankings were averaged for each item so that the lowest average represents the highest priority.

of the management structure. Our financial services have been automated for decades; this part of things is quite mature. But clinical systems are still very much paper based."

A big problem is getting medical staff to accept the new technologies—"We've got a lot of doctors who want to use a pencil." Not surprisingly, the RDT&E people reporting to the CIO are doing work on hand-held IT devices. As Slack (1993, p. 358) observes: "If a computer . . . is seldom used, it probably offers no advantage over traditional methods of processing and presenting . . . information. Attention should then be directed to the computer rather than the clinician." Apparently, the RDT&E units experimenting with new hand-held devices are providing just such attention.

The implementation problems identified by industry representatives contain a large managerial element but also user issues that are somewhat unique to the health care industry. The CIO just quoted continues, emphasizing, we believe, the importance of technology that is successfully adapted to the users' circumstances. Usability, then becomes paramount. The CIO observes that the implementation problems have to do with the reluctance of users to adapt to change. "It is a matter of users' desires, we need to change the people to be able to use the applications currently available. Health care is more of a cottage industry than say the retail banking industry. There is an independence issue here, just as with academic freedom. You wouldn't want someone telling you how to teach Economics 1; well, the doctors don't want someone telling them how to interact with their patients. There is a special relation between the physician and the patient. They don't want this turned over to machines."

The project team discussed major economic and technical barriers to progress with industry representatives. Regarding economic barriers, a common theme was that market pressures on health care seriously constrain investments in IT development. As one CTO reported, "Even though the price of IT is falling, the pressures exerted by "managed care" cause financial constraints that limit investment."

Regarding the technical barriers, technology officers cited the difficulties of adapting new technologies to legacy systems. Many systems in use are nearly obsolete, yet the health care organizations are trying to patch them together. Technology officers report that it is difficult to communicate because of the problems in adapting to the legacy systems. Such legacy problems are indicative of the systems nature of the technology in question. Legacy problems emphasize the time dimension of coordinating system technologies. And, according to some, the problem is compounded by the rapid rate of technological change and planned obsolescence on the part of vendors.

As we have discussed earlier, when describing the technology landscape, human interface problems are critical. The technology must be sufficiently usable to allow the special relationship between physician and patient to survive in the new IT environment. From the perspective of another technology officer who did emphasize the financial constraints, the technical solutions are essentially available, but the problem is social acceptance of sharing of confidential information across authorized users. “Sharing confidential health care records is something physicians and patients haven't accepted. I can solve their problems; the physicians won't accept the solutions.” Again, we believe that the general set of problems identified here suggest the importance of “usability” of technology. The importance of having technology that physicians and other clinicians find useful and usable is stressed by Slack (1993).

Our respondents pointed to another barrier—the legislative barrier—that has delayed the development of usable technology, although to an extent the barrier reflects the lack of acceptance of usable, reliable, and secure and authenticated IT. As one respondent explained, “There are 50 different state legislatures, all in different stages of saying that exchange of electronic information is illegal or legal. . . . Probably less than 10 states in the union accept electronic signatures. A physician's password is in effect his signature. But if he shares the password with someone else, is it still his signature? How many offices still have a rubber stamp for the physician’s signature? So the problem is not new, it has just appeared anew in an electronic context.”

7.7.2 Investment Impacts of Barrier Removal

Health care technology officers were unanimous in their belief that the industry would be investing more barriers in technology were removed. Estimates of the increase in investment varied. One respondent observed, **“**Just removing the technical barriers would result in a 50% or more increase in investment. If as well there were not the ‘economic’ barriers making spending difficult, investment would double.” Another observed, “Technology is evolving rapidly, but physicians are paying as little as possible for IT because of the financial constraints. . . . So yes, without financial constraints, there would be an acceleration, with more funds going to vendors.” Another CIO argues that not having the funds to invest is a significant economic barrier. “IT is more and more a key element to what we do. Everyone needs to realize that ...we need to spend more.”

Relaxing the social acceptance barrier would also result in more investment according to several respondents. For example, a government mandate for payment for services in telemedicine would greatly stimulate these types of services. As a result that would be “a great boon to investment”. Regarding the extent to which investment would increase if barriers were removed, “I can't answer except qualitatively, anything more would just be an uninformative stab in the dark. But, if the economic incentive for information management tools is increased, there would be “a very positive effect on investment.” Another CIO observed, “Yes, if people would accept the technology, more would be used. IT will never in my opinion be more than five to six percent of sales in the health care industry. We're at about 1.5% now, so double or triple that would be the change.”

For the industry as a whole, technology officers believe that overcoming barriers in technology development and implementation would result in revenue growth and productivity enhancement. Respondents observed that health care is an industry that depends on intercommunication. The impact would be especially great for hospitals. Their revenues would be greatly increased because the hospitals would be able to reach their physicians more readily and that is where the revenues are. Respondents observed that not only would revenues increase, additionally there would be a reduction in costs—patients and physicians wouldn't travel as much. Respondents believed that initial set up costs would be outweighed quickly by the cost reductions. There are large economies of scale; including the gains from a wider application of standards of practice. As one respondent observed, “The trend in the last 15 years is toward far few hospitals; . . . That trend will continue. . . . In health care, there will be maybe 500 organizations across the U.S. that would each have two to ten billion dollars in sales. So the effect would be a high market share in our local area and increased productivity.”

Our respondents' views of the technology barriers in health care are consistent with the recent comprehensive assessments by OTA (1995) and the Council on Competitiveness. (March 1996). The Council on Competitiveness (CoC) has identified barriers in technology in health care by focusing its study on four key sectors of the health care market: remote care (the use of telemedicine to deliver health care services to patients), personal health information and management (the insistence that patients take more responsibility for their own health care and the encouragement of such initiative with wellness programs and health information), integration of health information systems, and health care research and education. (Council on Competitiveness, March 1996) The CoC list of barriers is extensive; the barriers identified can be traced to the many uncertainties concerning IT applications in health care, and often these uncertainties can be tied to health care specific problems in achieving the IT performance goals articulated by NIST, that IT be usable, reliable, interoperable, secure, and scaleable.

Regarding the use of telemedicine for remote care, the CoC "identifies several barriers preventing widespread commercial adoption: lack of reimbursement, cumbersome licensing and credentialing requirements, malpractice issues, funding uncertainties, institutional inertia, telecommunications costs, and human resistance to change." Regarding personal health management, the Council finds: "Key barriers to wider dissemination of health-related information revolve around the authenticity and appropriate use of information amid the changing dynamics among patients, practitioners, and health care delivery organizations." (Council on Competitiveness, March 1996, Executive Summary)

Regarding the systems integration for health information, the Council finds that:

> many barriers are contributing to slow market development: high start-up costs, fragmented provider structures, rapidly changing affiliations among health care stakeholders, the slow development of standards for formatting and transmitting information, the proliferation of proprietary solutions, and concern regarding how to ensure privacy and confidentiality. Market growth will depend on the ability of the health care and information systems industries to solve the "many to many " problem: integrating many pieces and types of information, in many formats, on many platforms, from many stakeholder environments, for use in many geographic locations. (Executive Summary)

Clearly, there are usability problems that make IT applications in health care especially difficult:

> The health care delivery system has several unique characteristics that discourage the spread of information technologies. Health professionals perform a wide variety of tasks including rapidly changing combinations of "hands-on" care, inductive and diagnostic thinking, detailed record-keeping, patient education, and communication with colleagues. Most of the hardware and software approaches that address one of these aspects of medical practice intrude unacceptably on some other aspect: computers are not yet as useful, ubiquitous, and handy as the stethoscope and other common medical technologies. In addition, medical practice is extraordinarily complex and it changes rapidly. Systematizing even the process of performing medical procedures, much less rationalizing the language and scientific knowledge underlying those procedures, is an almost intractable problem. Despite the ongoing efforts of standards-setting bodies, no unified conceptual model exists that is powerful enough to construct the mapping between the information that must be stored in computer databases and medicine as it is practiced. In a sense, there is not yet a consensus about what information should be kept in computer-based patient records or how it should be described, organized, and indexed. (U.S. Congress, OTA, 1995, pp. 2-3)

Barriers in technology, notwithstanding, the promise of IT as a way to reduce costs while maintaining quality health care is great. Early and successful use of an integrated hospital-wide system of computing was reported at Boston's Beth Israel Hospital and Brigham and Women's Hospital. (Safran, et al., 1989; Bleich, et al., 1989; and Safran, et al., 1990) This system combined both the financial and the clinical sides of health care. Integrated computing systems help the clinicians provide patients with better care, and additionally the more accurate data has substantially increased the recovery of revenues from delivering health care. Usability, reliability, and the integration of the financial and clinical information in an accessible, interoperable system are key components of this early success of hospital-wide IT. Rapidly evolving IT and the need for ever-widening networks of providers, insurers, policy-makers, and consumers, have perhaps caused the technological frontiers to advance faster than the health care industry has been able to move forward to embrace helpful new technologies.

7.8 SUMMARY

In summary, health care is a widely dispersed industry undergoing rapid structural and technological change. In many respects, this change is very similar to the challenges affecting the other two industries we examined. Like the other industries, it has potential applications to transform both the business practices of health care and the basic way the "industry" delivers its services.

Health care also faces many unique challenges due to the dispersed nature of the industry, the extreme pressure for cost containment, and the difficulty of developing "systems" approaches. All of these challenges result in market failure, many of which could be addressed by NIST. In Chapter 8, the nature and scale of the barriers that lead health care providers to underinvest in IT are considered along with similar barriers confronting the banking and home entertainment industries.

8. CASE STUDIES: OVERVIEW AND POLICY CONTEXT

8.1 INTRODUCTION

In this chapter, we present the essential themes that emerged from case studies of three important service industries — retail banking, home entertainment, and health care. All three are in the midst of dramatic technological change, and the companies competing in these industries face many of the uncertainties and risks that lead to underinvestment. A summary of findings from all three case study industries is presented in each of the following broad areas of concern:

- Size and significance of the industries
- The competitive impact of IT
- The technology landscape
- The R&D function in the service sector
- Barriers to technology development and implementation
- Barriers to technology in a policy context
- Case study methodology insights.

8.2 SIZE AND SIGNIFICANCE OF CASE STUDY INDUSTRIES

Both individually and as a whole, the industries we studied are economically significant. Together they account for over 20 percent of private service sector employment. Each of these industries has an important indirect economic significance as well. By mobilizing savings and allocating credit across time and space, banking plays an important role in helping households cope with economic uncertainties. Technological improvements in banking can have a significant impact on the cost of economic transactions throughout the economy. Health care has become a major focus of public concern. In addition to its impact on the quality of life, technological change in health care is regarded as an important means of controlling health care costs. The home entertainment and information industries have extraordinary cultural and political significance. They provide an important conduit between the U.S. household and the outside world — politically and culturally.

8.3 THE COMPETITIVE IMPACT OF IT TODAY

All industries we examined in this report are prodigious consumers of information technology. Their role as lead buyers of embodied technology may provide them with a more significant role in the direction of technological development than the level of their formal R&D expenditures — or the size of their RDT&E staffs — would suggest. IT is one of the most important factors in the ongoing transformations of all three industries.

In all three industries, IT is being implemented in the context of rapid technological and industrial change. The convergence of technologies and industries is characterized by senior technology managers as “a tidal wave” and uniformly creates “a fog” in their technology planning and implementation processes. This industrial and technological convergence is occurring in historically highly fragmented industries. As a result, significant “cultural lags” are perceived to be slowing the convergence process.

The “high-tech stew” that is created by technological and industrial convergence creates both uncertainty and profound systems integration problems. Interoperability and legacy system integration problems are particularly pronounced.

Industry representatives uniformly cite standards-related activities as primary business policy issues. As buyers of technology, primarily, service sector firms are chiefly concerned with standards development efforts that produce compelling, widely adaptable standards, rapidly. It appears that many (perhaps too many) ad hoc collective industry efforts are oriented towards such standards-related activities and that traditional industry-wide “official” standard-setting organizations are perceived as lacking a focus that is consistent with the service providers’ priorities. Traditional standard-setting organizations are also perceived as being too slow and reactive to support the fast-paced tempo of IT developments.

The “tidal wave” of information technology appears to be shifting the balance of market power from suppliers to consumers, across the industries that we have analyzed. The proliferation of “channels” of communication, and information available through those channels, reduces information costs and switching costs for consumers. For service suppliers, competitive pressures to improve service content and to deliver services more effectively (utilizing IT) are key. The shifting balance of market power causes great uncertainty for service sector firms. What consumers will want; how fast they will adopt new technologies; and how they will utilize new services appears to be highly uncertain in the minds of industry planners.

Throughout these industries, strategic positioning appears to be an overriding concern of corporate strategy. Firms are positioning themselves horizontally (i.e., taking advantage of multiple service delivery modalities — wireless, cable, Internet) as well as vertically (i.e., attempting to better control service content production and delivery).

8.4 THE TECHNOLOGY LANDSCAPE

Corporate technology managers typically describe the technology landscape that they face as extremely chaotic. None were aware of anything resembling "technology roadmaps" that could be used to guide our analysis of industry-wide technology issues.[97] The pace of change is perceived by some to be too rapid for such efforts to be effective. In the words of one industry representative, "we are forced to navigate rather than plan." Despite this perception, most technology managers contend that such "roadmaps" exist for internal purposes, though they are more likely to be implicit than formal.

The absence of shared understandings of the technology landscape makes public investment planning that is technology-specific most difficult. Some explicit systematic discussion of the technological division of labor (for example, between tiers of the industry, or among large and small firms within a horizontal industry segment), of the nature of the underlying technologies (for example appropriability signatures), and the timing and level of technology investment by various key players are rudimentary components of such planning. Without a shared technological framework, at a minimum, such planning will be highly imperfect.

We were able to characterize technology frameworks for the purposes of exposition but these lack the specificity necessary for the systematic and balanced survey of service sector technological requirements. In banking for example, we perceive three broad categories of technology application with which to understand the main dynamics of technological development and implementation: channel access technologies, by which banks gain access to their customer base; customer targeting technologies, by which banks assess data for the purposes of defining financial services and targeting customer segments; and

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97 By "technology roadmap" we mean a document that includes some or all of the following: a taxonomic characterization of the important components of a system of technologies; a description of the state and direction of the various system components; identification of barriers to achieving the desired technological goals; identification of key players for each system component; an assessment of what organizations are "responsible" for advancing (or likely to advance) the technological objectives; a timeline describing when intermediate or end states are likely to be achieved; the resources level

back-office technologies, aimed at improving the efficiency of banking operations. In entertainment, we can distinguish between technologies that emphasize entertainment from technologies that emphasize information, but the distinctions between these paradigms are fuzzy. In health care too, broad categories of IT applications can be discerned: "back-office" applications, including the maintenance and communication of medical services performed and billing; "front-office" applications, including the maintenance and communication of patient health and treatment records; health service content, including the applications of IT to diagnosis and therapy; and health service delivery, especially the burgeoning of on-line health services.

There is some evidence to suggest that such roadmaps are emerging as an outcome of the chaotic environments in which service sector firms are currently operating. In banking, for example, industry-wide efforts are just underway to make sense out of what industry observers call the "vegetable soup" of collaborative efforts all aiming at apparently similar technology development and standardization issues.

Key Infrastructure Technologies: Each industry, indeed each firm, has a somewhat unique set of technologies, or technology implementation concerns, that are paramount. But some concerns appear to be common to all industries, even industries that are otherwise very different. Among the technology areas common to all three case study industries are the following:[98]

- Electronic commerce applications
- Cryptographic standards
- Firewalls & Internet-based tools
- Network scaling
- Wireless communication
- Data compression.

required to effect the desired intermediary or end states; and the likely source of those funds.

[98] A list of technologies was developed from material provided by NIST IT experts. (Perine, et. al., 1996) This list served two purposes in our interaction with industry. First, it provided a very useful focal point for discussions with corporate technology managers. In addition, the technology list kept the focus of our case study interviews relevant to NIST capabilities.

It is obvious too that some technology concerns cross industry lines because of similar service delivery strategies. For example, retail banking and home entertainment seem to share some similar service delivery strategies. Gaining ready access to the home is a priority for both of these industries, but is much less important for the health care industry at this stage in its technology evolution. In addition to the technology areas shared by all three industries, the following are common to banking and home entertainment:

- Monitoring & control for large networks
- Set top boxes for interactive TV
- Distributed databases.

As dissimilar as banking and health care appear with respect to service delivery strategies, they may have similarities — such as security and record-keeping requirements — that cause common concerns not shared as strongly with home entertainment. Among the technology areas of common concern to the banking and the health care industries are the following:

- Design for speech recognition hardware and software
- Data management
- Conformance tests for cryptographic standards
- Advanced authentication technology.

Similarly the home entertainment and health care industries express common critical concerns for the following technology areas:

- WWW and IPv6 security
- Systems management
- Systems integration
- Next generation Internet protocols
- Quality of service for multimedia & real-time applications
- Compression algorithms.

In an attempt to understand service sector IT needs from a functional standpoint, we asked industry technology managers to rank 5 IT performance attributes. It was anticipated that by combining ranked IT technology areas with ranked performance attributes, NIST IT specialists would gain a more specific understanding of each of the industries' needs. Respondents' rankings of IT performance attributes are presented in Table 8-1. While respondents typically had a very difficult time uncoupling and ranking these attributes for their industries, some differences between the industries are discernible.[99] The importance of usability and reliability across the sectors reflects the profound difficulty service providers are having convincing their own intermediary users and consumers to accept new IT-based modes of operation and service delivery.

Table 8-1. Ranking of IT Performance Attributes by Industry

Retail Banking*	Home Entertainment	Health Care
Usability	Interoperability	Usability
Security	Usability	Reliability
Reliability	Reliability	Scalability
Interoperability	Scalability	Interoperability
Scalability	Security	Security

* The ranking for retail banking is based on the authors' judgments.

8.5 THE R&D FUNCTION IN SERVICE SECTOR FIRMS

Aggregate R&D statistics, discussed in Chapter 1, indicate that the service sector accounts for an increasing share of the U.S. economy's total R&D activity. Interviews with service industry technology managers focused, in part, on the scope and nature of the R&D activities undertaken in their companies. For the three industries studied, we conclude that it is more appropriate to speak of the RDT&E (research, development, test, and evaluation) function of service sector firms than to speak of simply their R&D function; that the emphasis is on test and evaluation activities; and that the primary focus of this activity is information technology. In the three service industries discussed here, the emphasis is on information gathering, research on emerging vendors, pre-acquisition test and evaluation efforts, designing and

[99] It was anticipated that IT managers would view these criteria as discrete and rank them accordingly. Typically, however, they were viewed as integral and difficult to rank or weight.

monitoring pilot projects, assessing and monitoring software service agreements, and evaluating the applicability of IT protocols developed by standards development organizations.

What genuine R&D is performed in service sector firms often involves engagement with hardware and software suppliers. While independent R&D efforts by service sector firms have been unusual, industry technology managers report that they exert significant influence instigating and determining the direction of technology development by vendors. Often they engage in co-development efforts wherein service sector firms provide code and/or performance specification while hardware/software manufacturers are responsible for managing the productization process. In some cases, such joint efforts were then utilized to support standard-setting efforts.

There is a suggestion, at least, that service firms are engaging in more co-development efforts than in the recent past, and that the RDT&E function is becoming increasingly important. These changes are almost solely due to the impact of IT, in particular to the increased emphasis on the application of IT to service delivery and content, rather than to "back office" operations. As these technologies become an integral part of the basic service that firms deliver, internal control is perceived as more important.

RDT&E staffs are small but growing. Corporate technology managers sense that such staff growth is a response to secular changes in the nature of their industries, such as the integration requirements that are the result of industry convergence and the movement toward integrating IT into service content and delivery. For large firms, an RDT&E group of 15-25 people is typical. Often, this staff coordinates the efforts of additional engineering and RDT&E staffs at the divisional level. The technical focus of 80-100% of the typical RDT&E staff is on information technology.

8.6 BARRIERS TO TECHNOLOGY DEVELOPMENT AND IMPLEMENTATION INVESTMENTS

Throughout the industry trade press, and over and over in interviews with technology managers, three general barriers to greater IT investment are emphasized. First, industrial and technological convergence creates an intense strategic planning "fog." Second, industrial and technological convergence compound, and are compounded by, interoperability and legacy system integration problems. The description of the banking industry's problems in this regard is representative of other service industries we examined:

> The realm of current technology offers an abundance of problems and issues that have yet to be solved. Current technology is so complex, and already offers so many choices, that banks have their hands full with it. Only a portion of any bank's systems infrastructure can be state of the art at any given time, so the issue of simply catching up (where it makes sense to do so) can be a full time job. Banks would have a full plate if there were not going to be any more technological advances. (Steiner and Teixeira, 1990)

The third and final prevalent theme is that of shifting the balance of market power toward the consumer who, in turn, is regarded as hesitant and uncertain about how to use IT as a services access device. All case study industries are increasingly sensitive to the uncertainties of what the consumer will choose. The stakes of the wrong choice are high. If investments are made in one direction and the consumer moves in a different direction, the previous investment — and time — is lost and the switching costs can be enormous. In our view, these conditions lead to a high background level of uncertainty that surely dampens investment enthusiasm. In interviews with health care technology executives, it was estimated that greater acceptance of IT on the part of users (both final and intermediate users) could lead to a doubling or a tripling of IT investments.

Industry respondents uniformly argue that significant underinvestment results from readily identifiable barriers in technology development and implementation. For the home entertainment industry alone, estimates of the level of underinvestment in technology range from 30% - 300% across a variety of potential investment projects. For many of the key technologies identified by technology managers, specific barriers were identified and estimates of the underinvestments were made.

In the health care and retail banking industries, financial constraints were specifically identified. These financial constraints, caused by persistent cost reduction concerns, force hurdle rates up and investments down. Banks and hospitals alike identify short planning horizons (high hurdle rates) as a barrier to higher levels of much-needed investment. Bank executives describe planning horizons of no longer than 18 months, and health care technology managers describe the need for longer-term planning horizons to solve serious legacy system problems. They describe the gap between what is technically and physically required to provide IT-based operations, services, and service delivery, and what financial constraints impose. Estimates from health care technology managers suggest IT underinvestments of greater than 20%. These problems are compounded, in some cases, by overinvestments that were the result of "wildly inaccurate" projections of past waves of innovation. In banking, for example, the memory of overly enthusiastic investments in automatic teller machine (ATM) technology have cultivated a "careful attitude" toward such novel phenomenon as Internet banking.

Both health care and banking suffer from pervasive legacy system integration problems. Health care executives estimate that these problems cause IT underinvestments of 50% or more. Others, while unwilling to hazard a quantitative estimate, suggest that solving the legacy systems integration problem would be “a great boon” to investment. The legacy systems problem is only one manifestation of a much larger system coordination problem that affects service firms and their customers as well. Technology managers across all industries express acute uneasiness in the face of rapid technological change and rapidly-evolving IT system choices. For example, bank executives express grave concerns about being “stranded” by investments in the wrong network.

Home entertainment representatives provided estimates tied to specific technology issues. For cable service providers, the realization of improvements in video server technology could lead to a 2-3 fold increase in investment. And the mitigation of barriers to the implementation of video-on-demand technologies could lead to additional billions of dollars of investment a year by cable network operators. Similarly, entertainment industry executives estimate that more rapid progress on next generation digital compression standards could unlock investments to support billions of dollars in the home video market revenues. Advances in data compression standards are expected to lead to investment by television broadcasters as well, as these technologies will enable additional programming while utilizing existing satellite transponder capacity. Finally, entertainment industry technology managers' project that improvements in Internet protocols would result in a 30% increase in related IT investments.

Table 8-2 summarizes the anecdotal evidence of market failure derived from the three case studies.[100] This evidence is categorized by industry, by type of technology barrier, and by the most appropriate policy instrument available to NIST. Point estimates of the scale of underinvestment are indicated where available. The evidence presented in Table 8-2 could provide a starting point for NIST interactions within individual industries. We are confident that the problems identified reflect the major technology barriers being experienced by the respective industries. Also, the following cross-cutting issues

[100] The “evidence” presented in Table 8-2 is varied. It includes direct evidence of barriers, such as estimated underinvestment caused by barriers; indirect or circumstantial evidence, such as the existence of institutions organized to address barriers; and perceptual evidence, such as an expressed “need” for more rapid progress.

are clearly discernible: uncertainty about customer preferences; "legacy" interoperability problems; "distance" from the locus of technology development; and computer security issues.[101]

In summary, these barriers, and the associated underinvestment, are linked to economic conditions that are not conducive to proper functioning of the market mechanism. It is these market failures that constitute the primary justification for government participation in service sector technology development and implementation activities. There is ample anecdotal evidence of barriers to technology development and implementation that lead to the types of market failure that NIST is equipped to address. Coupled with the general statistical evidence of the service sector's substantial underinvestment in IT, the case studies suggest a potentially important role for NIST in support of the service sector. The nature of that role is the subject to which we now turn.

Table 8-2. Evidence of Barriers by Market Failure Type and Service Industry

Appropriate Policy Instrument	Type of Technology Barrier	Retail Banking	Home Entertainment	Health Care
	Recognition	• Individual co-development efforts with communications hardware suppliers • Formal horizontal collaborations (e.g., FSTC) • Historical inexperience with cooperative strategies • Unimagined IT applications • Locus of technology development outside service sector	• Collaborative ventures (e.g., CableLab, DVD Consortium) • Locus of technology development outside service sector (services poorly represented in many standards development activities, e.g., DAVIC) • Unimagined IT applications • Wireless technology (PCS) potential for "paradigm shift"	• Collaborative ventures with software developers (e.g., numerous ATP awards) • Locus of technology development outside service sector
Support for Generic Technology	**Long Time To Market**	• "Widely inaccurate" economic projections of past innovations (ATMs) • Customer preferences unclear	• Customer preferences unclear • Improvements in video server technology to enable VOD service (underinvestment: 300%)	• Intermediate customer preferences unclear & resistant to IT (underinvestment: 200-300%) • Long time to

[101] The evidence presented here was the result of open-ended questions regarding technological barriers and the resulting underinvestment. In Section 8.7.1 the results of a ranking of a standard list of 47 IT areas provides information needed to prioritize critical technology areas according to their pervasiveness.

				commercialization (e.g., imaging research)
	Excess Competition Among Developers		• Two or three home interface paradigms (TC, computer, teleputer)	
	Excess Competition Among Implementers	• Technology investments seen as critical to bank survival • Highly fragmented industry		• Pressures of "managed care" limit IT investment (underinvestment: 200%) • Highly fragmented industry
Support for Infratechnology Development	**Spillovers**	• Roadmaps emerging to make sense of a "vegetable soup" of collaborative/ standardization issues	• Digital copyright concerns associated with Internet/video-on- demand	
	Interoper-ability of Systems	• "Legacy" interoperability problems (associated with larger IT system coordination problem) • Physical networks • Software agreements monitoring	• Two or three home interface paradigms (TC, computer, teleputer) • Wireless technology (PCS) potential for "paradigm shift" • "Legacy" interoperability problems (associated with larger IT system coordination problem)	• "Legacy" interoperability problems (associated with larger intra- and inter-IT system coordination problems) (under-investment: +50%)
	High Transaction Costs (Info/Asset Sharing Difficulties)	• Formal horizontal collaborations (e.g., FSTC) • Historical inexperience with cooperative strategies • Roadmaps emerging to make sense of a "vegetable soup" of collaborative/ standardization issues	• Collaborative ventures (e.g., Cable Lab, DVD Consortium)	• Collaborative ventures with software developers (e.g., numerous ATP awards)
	Infra-technologies	• Progress on digital compression standards is too slow • Certification & acceptance marks • Emphasis on customer access technology • Computer security standards & protocols (major issue: protecting confidential information) • Network test & evaluation tools/ data compression standards	• More rapid progress on digital compression standards — "going beyond MMPEG-2" (investments to support $billions in video market revenues) • Improved Internet protocols (under- investment: 30%) • Computer security standards & protocols • Network test & evaluation • Compression algorithms	• More rapid progress on digital compression standards • Progress on EDI standards essential to HC cost reduction • Computer security standards & protocols (major issue: sharing confidential information) • Network test & evaluation • Compression algorithms

8.7 BARRIERS TO TECHNOLOGY: THE POLICY CONTEXT

In this section the proceeding summary of technology barriers and related underinvestments is placed in a context that can support policy discussion and choices by NIST. In section 8.7.1 the discussions of the key technologies (section 8.5) and barriers to technology development and implementation (section 8.6) are interpreted through the lens of appropriate policy instruments discussed in Chapter 3. In section 8.7.2, the private service sector's major institutional responses to technology barriers are summarized as a prelude to the discussion of policy implementation in the final chapter.

8.7.1 Matching Policy Instruments and Barriers to Technology

As discussed in Chapter 3, barriers to technology development and implementation can result in market failures and underinvestment. The appropriate public policy response to these technology barriers depends on their specific nature. Briefly, general riskiness associated with technology development and implementation can be addressed through broadly applicable policies such as tax incentives. While our case studies clearly show high levels of general risk, the types of problems identified in this report are not appropriate for such solutions. Rather, the sources of market failure are identified and described at a level of detail that allows some discussion of appropriate policy instruments. This is the level of analysis required for NIST to begin to develop specific institutional responses to service sector market failures.

As observed by Tassey (1997), ferreting out the nature of the barriers to further development or implementation requires sophisticated policy analysis and significant input from industry. The case studies in this report go some distance in fulfilling this requirement. And while it is often not easy to isolate the exact nature of specific barriers, an attempt is made here to categorize cross-cutting barriers for the purpose of indicating a potential course of action for NIST. However, in any specific case a finer grain analysis, and more detailed industry input, is likely to be required prior to any institutional response.[102]

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[102] Ideally, a thorough review of the technologies at issue would precede the interview, so that specific economic dimensions of the topic could be explored. For the most part, technology reviews for the case studies presented here were conducted simultaneously with the industry interviews. In addition, interviews for these case studies covered a wide variety of topics, partly to discover specific barriers to technology and partly to ascertain the economic significance of these barriers. Ideally, each barrier could have been pursued in detail and then, once a cross-cutting view was established, additional questions could be raised and addressed. Due to the initial sweep of the inquiry for each of the case study industries, this kind of focused analysis was not possible. These case studies were understood to be anticipatory of detailed discussion between NIST technology experts and their industry counterparts. The appropriate level of detail could be ascertained in such meetings, or in anticipation of them.

General risk. While assessing general risk is not the focus of our investigation, it invariably was present as the "background noise" to understanding and exploring more specific types of barriers. For example, financial constraints were often mentioned, as were planning horizons (short planning horizons = high hurdle rates) of no more than 18 months. A health care -related estimate suggests that with reasonably less stringent financial constraints IT investments would double.

In all cases, industry observers expressed a great deal of uncertainty. The roots of this uncertainty are many: the pace of technological change; the complexity of dealing with that change operationally in such information systems-dominated businesses; the dramatic consolidations taking place in these industries; and especially in banking and home entertainment, the industrial convergence phenomenon. This sense of uncertainty is no better expressed by the banker's profound strategic planning question, "What is a bank?"

Specific risk. Case study analysis provides a window onto specific types of risk that arise from a market's or a technology's stage of maturity, its degree of publicness, or its potential to reduce market transaction costs. (Tassey, 1997) Table 8-3 organizes service sector infrastructure technologies according to the scope of their application and type of policy instrument appropriate to their development. Consider the technology areas common to all three case study industries (column 1) discussed in section 8.6 (electronic commerce applications, cryptographic standards, firewalls & Internet-based tools network scaling, data compression, wireless communication). Of these, the private sector appears to have a dominant role in developing and implementing electronic commerce applications, but the fact that all three industries ranked this technology area as critical to their future, suggests, at a minimum, some public policy concern to identify and address any cross-cutting barriers (such as interoperability and security issues). Perhaps there are underlying generic technologies involved in electronic commerce applications that would be appropriate targets of collaborative research of the type supported by NIST's Advanced Technology Program.[103] In the other five technology areas, NIST information technology experts identify important issues appropriate to public sector involvement. In fact, NIST is currently engaged in the development and implementation of infratechnologies that support these technology areas, though, to our knowledge, these have not been focused or organized to support any special needs of the service sector. (Perine, et al. 1996)

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[103] Such collaborative efforts would want to ensure representation of vertically related partners, including service sector

While the high-priority technology areas common to retail banking and home entertainment — monitoring and control for large networks, set-top boxes, and distributed data bases — are the focus of much private investment, their priority ranking by representatives of two very different industries suggests that generic technologies and infratechnologies may underlie the effective service delivery strategies that these technologies support (column 2). Further evidence of the potential for a public sector role in providing infrastructural support for at least one of these technology areas (set-top box technologies) is suggested by intensive standards-related activities that have surrounded the regulation of interactive TV services. These activities pertain to the existence of complex systems of interfaces that can retard interoperability and timely adoption of technologies. Interactive TV technologies, such as set top boxes, are critically important to the service delivery strategies of service industries and firms.

The critical technology areas common to other service industry pairs (health care and banking, health care and home entertainment) more clearly involve technologies in which NIST does provide infrastructural support (conformance testing for cryptographic standards, authentication technology, next generation internet protocols, multimedia quality of service tools, and compression algorithms). Even where the proprietary role in technology development would appear to dominate (e.g., design for speech recognition hardware and software), the cross-industry nature of the priority accorded this and other technology areas (data management, systems management, systems integration) increases the probability that elements of generic technology are important to their fullest development and implementation.[104]

Listed in column 3 of Table 8-3 are technology areas considered critical to members of single industries. These would be the lowest priority for technology policy initiative unless additional information allowed the selection of individual service sector industries as recipients of technology policy support.

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companies.

[104] NIST's ATP has funded the development of both pen-based and spoken language interface projects in the past. ATP has also organized "focused programs" to advance the development and implementation of generic health care technologies.

Table 8-3. Cross-Cutting Infrastructure Technologies and Appropriate Policy Instruments

Appropriate Policy Instrument	Cross-Cutting Technologies	Inter-Industry Technologies	Intra-Industry Technologies
Support for Generic Research	• Electronic Commerce Applications	• Monitoring & Control for Large Networks • Set-top Boxes • Distributed Data Bases • Design for Speech Recognition Hardware/Software • Data Management • Systems Management • Systems Integration	• Operating Systems & Utilities (*Banking)* • Video Servers (*Entertainment*) • Hierarchical Mass Storage Systems (*Entertainment*) • Virtual Reality (*Entertainment*) • Techniques for Manipulating Unstructured Text (*Health Care*) • Vizualization Methods for Complex Visual Information (*Health Care*) • Image Recognition & Processing (*Health Care*) • Scaleable Parallel Systems (*Health Care*) • Software Testing & Analysis Tools (*Health Care*) • Open Distributed Processing (*Health Care*)
Support for Infra-technology Development	• Crytographic Standards • Firewalls and Internet-based Tools • Network Scaling • Data Compression • Wireless Communication	• WWW & IPv6 Security • Conformance Testing for Cryptographic Standards • Authentication Technology • Next-generation Internet Protocols • Multi-media Quality of Service Tools • Compression Algorithms	• User Interfaces & Information Access (*Entertainment*) • Multimedia Protocols (*Entertainment*) • Internet Security Policy Development (*Health Care*) • Vulnerability Analysis & Testing (*Health Care*) • Multimedia Collaborative Computing (*Health Care*) • Common Windowing Protocols (*Health Care*)

It is very clear that across the service industries examined, the broadly defined technology areas of computer security (cryptographic standards, firewalls & internet-based tools, conformance tests for crytographic standards, advanced authentication technology) and networking (network scaling, data compression, wireless communication) are the dominant concerns of the service sectors. In both of these areas, NIST is involved in providing technology infrastructure support.

Whether it makes sense to orient NIST's ongoing efforts in these technology areas toward the service sector's special needs, indeed if infratechnologies can be construed as sector specific, requires deeper interaction between technical specialists in NIST and industry.

Given the scale of the underinvestments that are occurring in the service industries we examined (ranging from 20% to 300% in specific areas), and the common need for a broad range of technology infrastructure elements (especially those related to computer security and networking), it is clear that targeted technology programs are appropriate and that they can foster greater technology investment and economic growth in the service sector. To understand the specific roles that NIST can effectively play in any particular technology area requires further detailed discussions and negotiations between technical experts representing NIST and service sector firms respectively. In discussions with corporate technology managers, all expressed a willingness to engage in such a dialog.

8.7.2 The Private Sector Response to Technology Barriers

In each of the case study industries, firms are responding to barriers in at least 4 ways. First, they are investing considerable funds into coping with IT development and implementation barriers. As we indicate in Chapter 2, the cost of IT implementation can be four to five the times the investment in hardware and software. Second, firms are increasingly investing in technology development, typically in the form of co-development projects with suppliers in the manufacturing sector. Third, they are engaging in collective R&D efforts with other members of their industry (though these, too, often involve manufacturing sector participants). Finally, they are engaging in standards-related activities.

There appears to be considerable overlap in these activities. All but the second are considered initial evidence of (potentially incomplete) responses to market failures. Even co-development efforts can be related to market failure problems, to the extent that they are related to standards-making activities. It is not uncommon for co-development efforts between service sector firms and their hardware or software suppliers to result in products that are put forward in standards-related efforts. Standards efforts, in turn, are evidence of (perhaps incomplete) collective responses to technology system complexities that often lead to underinvestment in technology and market failures. We contend that collective industry responses are located in the "neighborhood of market failures" and are, therefore, likely to offer a window onto an appropriate supporting role for NIST. In other words, we interpret collective action as the first line of circumstantial evidence that something is amiss with the functioning of the market mechanism; something that demands more than singular action on the part of competitive firms.

For example, the Financial Services Technology Consortium (FSTC) and the Bankers Roundtable's newly formed Banking Industry Technology Secretariat (BITS) represent two responses by the retail banking industry to technology development and implementation barriers. They also provide an insight into how NIST might appropriately support service sector responses to market failure. The FSTC, in what participants describe as its "adolescent phase," has already involved public organizations — in the form of Technology Reinvestment Project funds and National Lab participation. The BITS is in its "infancy" but defines goals (such as the creation of a "certification process" and "acceptance marks") that, *ceteris paribus*, are clearly within the scope of NIST's concern and core competency. These two organizations are representative of emerging economic forces affecting the development and implementation of banking technology.[105]

FSTC is a collaborative R&D effort aimed at providing open solutions to problems confronting the banking industry as it moves into the world of internet banking in the not too distant future. Incorporated in 1993, FSTC has involved representatives of banks, other financial service providers, IT hardware and software companies, national laboratories, government agencies, and universities.[106] FSTC currently has about 90 member organizations and sponsors project-oriented collaborative research & development on interbank technical projects affecting the entire financial services industry. Particular emphasis is placed on active projects involving development of the internet and supporting a smooth transition toward an integrated global electronic commerce.

Currently, FSTC projects include: the Interbank Check Imaging Project, aimed at exchanging digitized computer images of paper checks using new open systems of computer platforms and

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[105] While there are undoubtedly other collaborative organizations whose examination would throw light on our subject, industry representatives believe that collaborative banking organizations with an explicitly R&D focus were few and far between.

[106] The government agencies have included: the U.S. Department of the Treasury, the U.S. Postal Service, the National Security Agency, and the Export-Import Bank. National laboratory participants have included: Oak Ridge, Lawrence Livermore, and Sandia. Our impression from interviews with FSTC bank participants is that the role anticipated for the national laboratories in the early stages of FSTC never materialized.

technologies; the Electronic Check Project, to validate the business and technological risks and opportunities for an all-electronic financial instrument; the Electronic Payments Project, to develop a broad architecture that enables electronic commerce process over public networks; and the Fraud Prevention and Control Project, to investigate how to improve fraud detection and prevention for interbank information sharing. Successful implementation could mean the reduction of check processing costs by as much as 33 percent, the secure integration of existing proprietary bank infrastructure with rapidly growing public networks, and the demonstration of effective fraud detection technologies and methodologies.

FSTC is one of a handful of bank-related organizations that are pursuing similar collective solutions to what for a long time have been proprietary solutions to IT systems issues. Other organizations pursuing a similar or complementary course include: CommerceNet, the Joint Electronics Payments Initiative (JEPI), the XIWT, the IISP, the National Association of ClearingHouses, and the World Wide Web Consortium (WWWC). All these organization are dedicated to some extent in developing and promoting the infrastructure for Internet banking. The existence of so many initiatives with apparently overlapping objectives has recently given rise to the Bankers Roundtable's Banking Industry Technology Secretariat (BITS). BITS was formed, in large part, to organize and focus what one observer calls "the primordial soup swirling around internet banking." BITS has identified over 40 organizations with complementary or overlapping missions and has proposed an number of initiatives aimed at cooperatively facilitating "the evolution of a seamless electronic financial services delivery and payments environment that will have the capability of linking customers — at their choice — with the marketplace through banks." (Bankers Roundtable, 1996)

BITS key initiatives are: to accelerate the establishment of new electronic payment and product delivery systems through the development of interoperable specifications and standards; to create, through a certification process for providers of banking products, an infrastructure for the safe and secure electronic environment that will embrace bank brands and respect consumer privacy; and to enhance consumer confidence, via an "Acceptance Mark," and evaluate the feasibility of industry-driven payment certificate authentication and real-time settlement.

In the health care industry too, we find similar collective responses to technology barriers. Health care industry representatives identified and emphasized the standardization efforts underway throughout the industry. There are many important standardization actions in progress. HL7, ASTM, COBRA Medical Standards, X12 EDI Standards, and more generally work on technological standards for open systems and the Internet.[107] Respondents emphasized the pressing need for such work on standards, especially electronic data interchange standards. A recent OTA analysis of the role of technology in the health care industry stressed the importance of such efforts to achieving the cost reduction that the public is demanding:

> Until standards are in place and compliance is widespread, costly activities—such as maintaining multiple formats for health care information, dealing with exceptions, and developing new interface software as new proprietary approaches to managing health information become fashionable—will continue to offset some potential savings of processing health care records and transactions electronically. . .
>
> The development of technical standards is primarily a private-sector activity. However, it could be accelerated through federal participation in developing standards that would encourage information exchange and protect the privacy of participants in the health care system, and through expeditious implementation of such standards in all federal health care matters as a catalyst for their adoption by the private sector. (OTA, 1995)

A recent survey of service sector R&D collaborations sheds additional light on how the various collective responses to market failure overlap in practice. (Leech and Link, 1997) The survey found: i.) that the primary objective of many formal service sector R&D collaborations is to gain access to complementary research or technical skills that are unavailable to individual service sector firms; ii.) that the collaborative R&D undertaken by service sector firms was less oriented to basic research than non-service sector collaborations; and iii.) that formal collaborative R&D projects often have standards- and protocol-related objectives (i.e., are more infratechnology focused), more so in fact than collaborative R&D projects undertaken in non-service industries. On the basis of this analysis and the findings of our case study investigations, we conclude that collective industry activities of all kinds are typically attempts to

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[107] The Consolidated Omnibus Budget Reconciliation Act of 1985 (COBRA) governs continuation of health care coverage requirements between two employing organizations, placing the burden of compliance solely upon the employer. Prior to COBRA, when an individual was no longer employed by a sponsoring organization, he or she and any dependents would either be discontinued from insurance coverage or would have the option to continue coverage under a modified plan. While many of these plans complied with conversion options and respective state laws, the provisions were not uniform.

Health Level Seven (HL7) is an application protocol for electronic data exchange in Health care environments. The term "Level 7" refers to the highest level of the Open System Interconnection (OSI) model of the International Standards Organization. In the OSI model the functions of both communications software and hardware are separated into seven layers or levels. The seventh level refers to the application level. The application level defines the physical format of a message, or the location of the actual fields of each electronic message. In June 1994, HL7 became an ANSI Accredited Standards Organization.

The ASC X12 (a designation assigned by ANSI) was chartered to develop the structure, format, and content of electronic business transactions conducted through Electronic Data Interchange (EDI). The result of the ASC X12 committee's efforts are the ANSI X12 Standards.

address both technology-specific types of market failures (e.g., high risks due to technical complexity, requiring technical expertise not available to the firm) and market-related types of market failure (e.g. high transactions costs associated with systemic nature of IT that standards-related activities attempt to address). Moreover, it appears that NIST's mission and expertise are highly complimentary to the objectives of these efforts.

8.8 CASE STUDY METHODOLOGY INSIGHTS

Case studies involve a process of discovery. They often raise as many questions as they answer. These case studies answered numerous questions that could not be addressed successfully by other means. We identified specific technological concerns considered critical to three important service sector industries. We identified perceived barriers to the fuller development and implementation of these critical technologies, and we obtained some sense of the magnitude of the underinvestments associated with these barriers. Applying the logic of market failures we are able to understand, generally, the market conditions that appear to lead to underinvestments in technology.

The case study investigations also led us to conclude that the body of economic literature through which we understand the logic of market failure has two shortcomings. The first is that it provides very little discussion about the kinds of evidence of market failure that would be most useful to applied case studies. As an important tool of technology policy, improvements in the applicability of market failure concepts is much needed. "Tools" with which to identify and assess the presence and degree of market failures, in the absence of complete information, are necessary, especially in support of prospective policy analysis.

The second shortcoming of the market failure literature, as it applies to the service sector, is that it is focused almost exclusively on the supply of technology at the expense of attention to demand. While the logic of market failures clearly applies to both the conditions of demand and supply, the bulk of the discussion to date is rooted in a production-oriented paradigm. Service sector firms are primarily consumers of technology. Their underinvestment is in large part caused by their economic conditions as buyers. Service sector firms are also forced to understand, and to respond to final consumers. It appears that some barriers to the service sector's greater investment in technology are rooted in economic conditions faced by final consumers. These market failure modes have received far less attention by economists and policy makers. While we do not claim to have solved, or even adequately formulated these issues here, we believe they are worthy of consideration as further analyses of the service sector market failures is undertaken.

9. DIRECTIONS IN TECHNOLOGY POLICY FOR THE SERVICE SECTOR

9.1 WHAT WE HAVE LEARNED

According to the national statistics reviewed in Chapter 2, the development and implementation of technology is increasingly important to the service sector of the economy. Because of the importance of the service sector to national economic growth, and because technological innovation is the single most important source of growth, technology policy in support of the service sector is an important area of policy concern.

Except for the communications services industry and the computer services industry, the service sector is for the most part a consumer and lead user, rather than a developer, of technology. Nevertheless considerable resources are expended by service sector firms in support of co-development efforts and, more importantly, in the testing, evaluation, and implementation of technology. NIST's special capabilities in test and evaluation practices, and its historical role in standards development activities (both of which are important to service industries) should provide a good foundation for interaction with industries across the service sector.

IT is the single most important focus of all technology development and implementation in the service sector. Between 80 percent and 100 percent of RDT&E staff time in the large service sector firms studied is dedicated to IT and IT-related issues. ITL's new institutional focus on IT is another reason to expect successful interaction with a broad mix of service industries.[108]

Increasingly, we believe, IT in service sector firms is moving from "back office" applications forward, to become an integral part of service content and delivery, and as this "phase change" occurs service sector RDT&E staffs will grow and the share of internally developed technology, relative to the total cost of technology, will grow. More importantly, this phenomenon sheds new light on the role of technology in the service sector and, potentially, on NIST's role in supporting the service sector.

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[108] On December 9, 1996, NIST announced the formation of its new Information Technology Laboratory, a consolidation of the former Computer Systems Laboratory and the Computing and Applied Mathematics Laboratory.

As stressed throughout this report, the existence of market failures— breakdowns in the incentive structure that drives private investment — provides the chief economic rationale for government involvement in technology development and implementation. We have argued that a cogent approach to government technology planning requires an analytic framework that can effectively differentiate types of market failure according to the various policy instruments best suited to their mitigation (Chapter 3); we have demonstrated in the case study chapters that such a framework can be applied effectively to discover and discern the most serious areas of market failure; and (in Chapter 8) that it is possible to apprehend cross-cutting specific technology areas that are critical to service sector growth . What is required beyond all this is a concept of institutional engagement — the *modus operandi* by which NIST delivers generic and infratechnologies to the service sector.

In the following sections we first posit a refinement to the conventional understanding of the role of the technology infrastructure in the service sector. The succeeding section will suggest an approach to NIST engagement with the service sector.

9.2 A SERVICE SECTOR-SPECIFIC TECHNOLOGY GROWTH MODEL

In Chapter 1, the technology growth model developed by Tassey (1995) was explained. This model recognizes an important "division of labor" among the various "estates" in a nation's system of innovation — universities, the private sector, government — and describes how these technology estates interact to effect economic growth.

In the case study analyses presented is this report, we find evidence to support the view that there are important extensions to the original Tassey model:

> [The original model] more accurately represents a manufacturing firm or industry than one in the service sector. Thus, limiting the conceptual framework to this representation would contribute to a somewhat out of date focus of R&D policy in which most technical infrastructure is still oriented toward the manufacturing sector, with only a slow shift toward support of information technology and services more generally. (Tassey, 1997)

It has been observed that even within the manufacturing sector there are variations in the role of technology, and that for one of those variations — supplier dominated industries — investments in new machinery and equipment, acquisition of hardware and computers, and manpower training are often more meaningful indicators of technological change than the firm's own R&D efforts, despite the fact that some internal R&D is performed. (Brouwer, 1995)[109] Thus far, the supplier-dominated model is completely consistent with the findings presented throughout this report. But this model goes on to suggest that, the similarity of supplier dominated industries (manufacturers or service providers) is based in large part on the "process orientation" of the technology implementation. These supplier-dominated industries are thought to "concentrate on process rather than product development."

In our view, this model misses an important dynamic: the "phase shift" in the application of IT from the "back office" forward to content development and delivery discussed in other models of service sector innovation. Our findings are more consistent with a dynamic model of innovation; with the proposition of an innovation life cycle — or "reverse product cycle" — that propels the evolution of IT implementation from the "back office" forward to "new product" development.

In describing the conditions for a phase shift in the application of IT toward product innovation, Barras clearly anticipates the main outline of our findings. His model foresees the phase shift toward the use of IT in the development of service content and in service delivery. Two important aspect of that shift are the change in the point of consumption (which we see very clearly in all three case study industries), and a change in the balance of market power toward the consumer (which appears very clear in the case of home entertainment and retail banking with the proliferation of "access channels"). (Barras, 1989) In 1986, Barras could see that progress toward this "third stage" had hardly begun and that it required the "progressive digitization to a broadband network capable of transmitting text, data, voice, and live pictures." Today those capabilities are either near, or fast approaching, the "state of the shelf."

Similarly, Mitchell's (1989) model of innovation in the service sector stressed the following: the service provider's imperative to control or influence hardware or software design (which case studies reveal in terms of co-development efforts); the necessity of the services to integrate technology into complex systems or organizations (which case studies reveal in terms of the imperatives of interoperability, especially the interoperability of current, past and present IT elements); the technical demands of operating these complex systems or organizations on a daily basis (which case studies reveal in terms of the extensive test and evaluation processes to assure error-free IT introductions and adaptations); maintaining that

[109] Brouwer employs a taxonomy developed by Pavitt (1984) to interpret the findings of a European service sector innovation survey.

complex system to deliver services reliably (which case studies reveal in terms of the high rank according to reliability as an IT performance parameter); and the prominent role of the end users as the direct customer (which case studies reveal in terms of emphasis on access to customers "wherever they are," and the uncertainty about consumer preferences that burdens many a service sector IT investment project). In our view, the "phase shift," that appears to be occurring across the service sector, in the application of IT forward to content and delivery (over and above its use to dramatically increase efficiency in 'back office" and "front office" functions) accentuates all these facets of the services market. What this means for Tassey's original technology-based economic growth model is characterized in Figures 9-1, 9-2, and 9-3.[110]

Figure 9-1. The Two Faces of Service Sector Technology Infrastructure

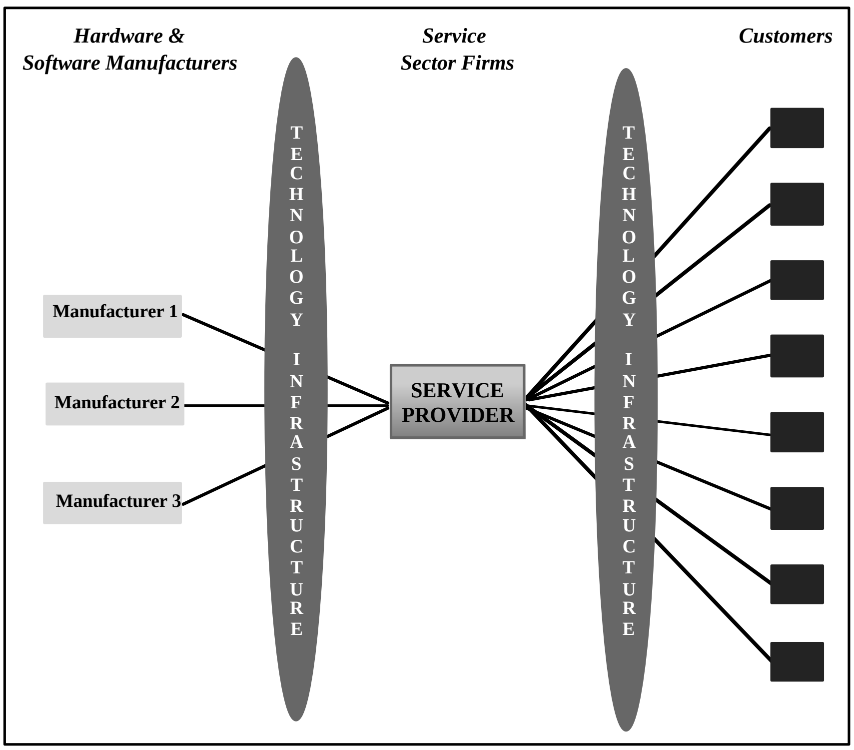


Figure 9-1 describes the *essential* complexity of the role of technology in the service sector. There are two fundamental interfaces in the service provider's use of IT: one between multiple hardware and software vendors and the service sector firm; and one between the service sector firm and the consumer.

110 The depiction of the technology infrastructure shown in Figures 9-1 through 9-3 are consistent with the model of service sector technology infrastructure developed by Tassey (1997).

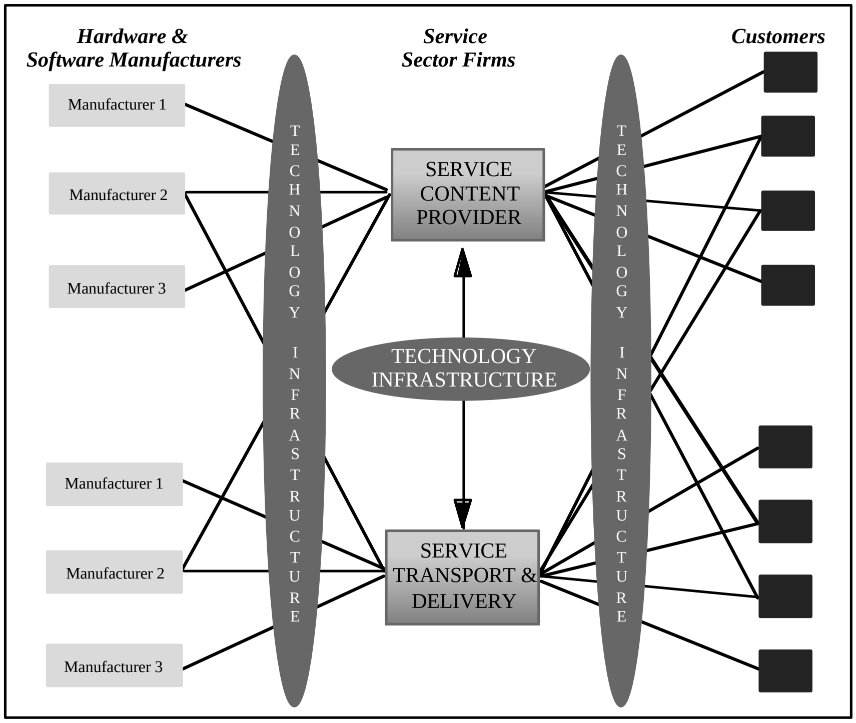
The service sector RDT&E function has emphasized test and evaluation activities *vis-à-vis* hardware and software vendors but, as noted throughout this report, there have also been co-development relationships with these vendors. We believe that, increasingly, service sector RDT&E functions are also engaged with a very different kind of R&D regarding their interactions with consumers. Our case study interviews found examples of service sector attention to both the hardware/software facets of this provider-customer interface (e.g., bank research efforts geared to biometrics to ensure greater security) as well as the content aspects of the interface (e.g., entertainment company research on "how to appeal to the consumer's sense of exploration"). The literature too suggests that, increasingly, service sector firms must be concerned with R&D in the areas of human factors, psychology, and applications design that address the provider-customer interface. (Mitchell 1989)

Within this framework, the provision of NIST's technology infrastructure occurs at both interfaces, for example, supporting increased interoperability through support for vertically organized generic co-development efforts, or the development of techniques and tools for assessing complex system-subsystem-component compatibility. At the service provider-customer interface, organizational processes (like the National ISDN Users), or infratechnologies to advance or characterize the security, reliability, and usability of service delivery technologies, are likely to be appropriate and desirable.

Figure 9-2 addresses another layer of complexity. Here we capture the basic elements of the service sector supply chain: service content (movie production, news reporting, financial instruments) and service transport and delivery. To some extent the interoperation of content providers and service deliverers is accomplished by means of vertical integration with manufacturers. Nevertheless the need for technology infrastructure *within* the service sector should not be overlooked. As service delivery modalities (cable, telephone/Internet, broadcast, and wireless) continue to converge, the technology infrastructure must be there to support it. This adds another dimension to NIST's technology infrastructure role.

Finally, Figure 9-3 attempts to capture the full complexity of the service sector's requirement for technology infrastructure. In addition to the manufacturer and customer interfaces depicted in Figure 9-1, and the intra-sectoral content-delivery interface addressed in Figure 9-2, here we also capture the intra-industry interface that is so important to the physical networks that characterize much of the service sector. In health care, retail banking, and home entertainment, the physical interconnection among service providers can involve barriers (in the form of security concerns) to greater utilization if IT.

Figure 9-2. Intra-Sectoral Technology Infrastructure



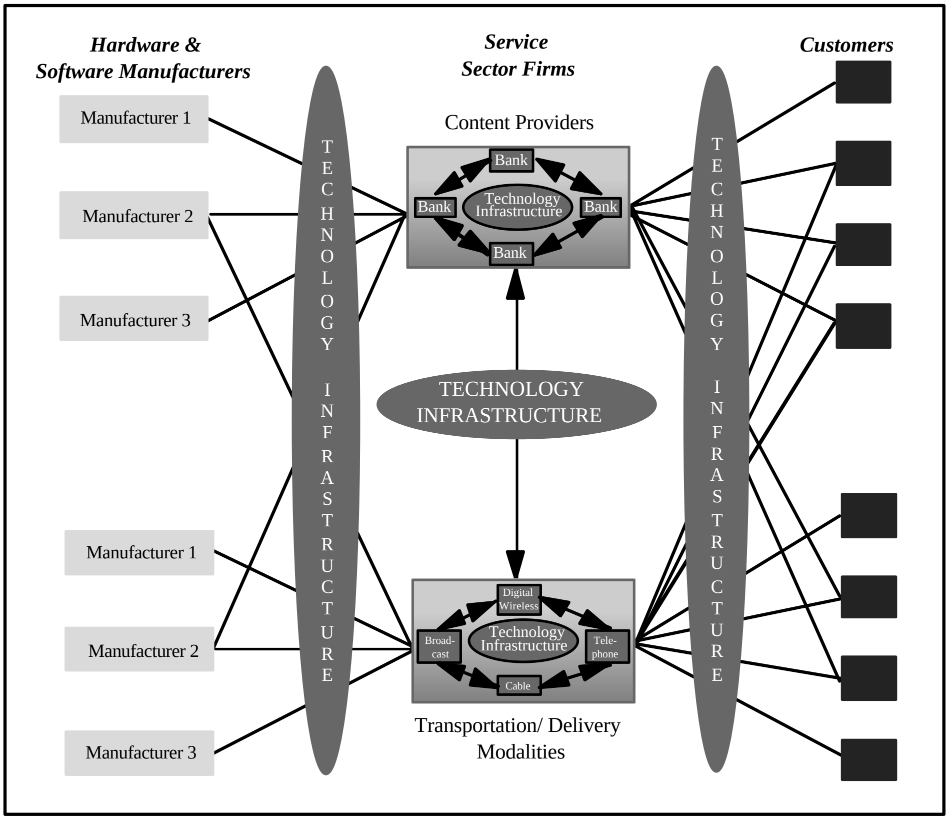
The service sector is structurally complex. The role of the technology infrastructure in the service sector is extensive, supporting the interaction of markets at many levels and at many stages of the value chain that runs from manufacturing to the final consumer. Both generic and infratechnologies can mitigate the barriers that lead to market failure in several aspects of the service sector's complex structure.

Given this complexity, even with knowledge of the nature and general structural location of market failures, how do policy makers determine a mode of engagement through which to exercise market- and technology-specific policy instruments in support of the service sector? Historically, NIST has "engaged" the manufacturing sector, in part, through its participation in the voluntary standards development process. As described in the following section, this presents a challenge in the case of the service sector.

9.3 THE LOCUS OF SERVICE SECTOR TECHNOLOGY POLICY ENGAGEMENT

This section presents a general approach to NIST's interaction with the service sector. This approach synthesizes our understanding of the evolution of the IT standardization process (a poorly understood aspect of industrial activity generally, according to Hawkins (1995)) with our

Figure 9-3. Role of Technology Infrastructure in the Service Sector



understanding of service sector needs in the face of barriers to technology and market failures. We emphasize greater involvement by NIST in strategically selected, ad hoc service sector efforts to address standards-related issues in other than (perhaps in addition to) traditional voluntary standards fora. Our understanding is that traditional standards organizations are perceived as remote from, and not focused on, the pressing technology issues facing service industries. If NIST is to successfully engage the service sector, it must do so where key problems are being identified and addressed.

One of the primary ways NIST has supported the manufacturing sector of the economy is through participation in, and support of, voluntary standards organizations.[111] In a technology-based economy,

[111] In recent years, NIST — through its Advanced Technology Program — has also emphasized other forms of infrastructural support The following discussion is focused on NIST's role in supporting standards-related activities, support that Tassey categorizes as the provision of "infratechnology." In practice the development and implementation of infratechnologies and generic technologies often occurs together, especially so in the service sector. Where appropriate our discussion of standards-related support should be construed to include support for generic technology as well.

standards are taking on increased importance due to the complexity of new products, the speed at which new models come into being, and the fact that these products are frequently embedded in systems whose effectiveness is, in turn, dependent on the interfaces between the components. (Tassey, 1995b) One of NIST's traditional roles in this regard has been to develop methodologies for assessing and assuring system "fit." This is a prime example of NIST's role as a developer and disseminator of "infratechnology."

The standards development process — especially for IT standards — is under severe strain. Speed in standardization is essential for the future of IT, and most standards bodies are simply not geared to operate as quickly as needed. (OECD, 1991) Yet despite this "growing and widespread dissatisfaction," no new coherent approach has emerged. (Alexander, 1995) The change in the pace and complexity of IT and its myriad application, along with greater recognition of the importance of the quasi-public goods nature of certain technology elements, has caused several new types of standards-related organizations to emerge. For example, Cooperative Research and Development Agreements (CRADAs) between government technology organizations and industry often have the early development of infratechnologies as their objective. (Tassey, 1995)

Other types of organizations, such as RJVs and private consortia, have emerged as well, some expressly formed to bypass the formal international standardization process by delivering sponsored de facto standards ratification by the market. (David, 1995) That said, standardization still ranks among the least understood industrial phenomena, and the debate about the role of the government regarding IT-related standards-making processes is in a state of turmoil according to knowledgeable observers.[112] (Hawkins, 1995; David, 1995) For our purposes, we assume that because of the large public spillovers NIST has generated by supporting the standards development and implementation process (See Tassey 1995a), their support of service sector infratechnology will also be beneficial. Still, it is unclear what the optimum forms of participation might be.

According to analysts of the standards-making process, many difficulties must be resolved if IT standards are to remain effective:

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[112] Paul David describes the economic logic of public policy concerning technical standard-setting in general as in an unsettled and confusing state. He observes that the "present turmoil" is especially noticeable in regard to standards affecting the information, computer, and telecommunications industries. (David, 1995).

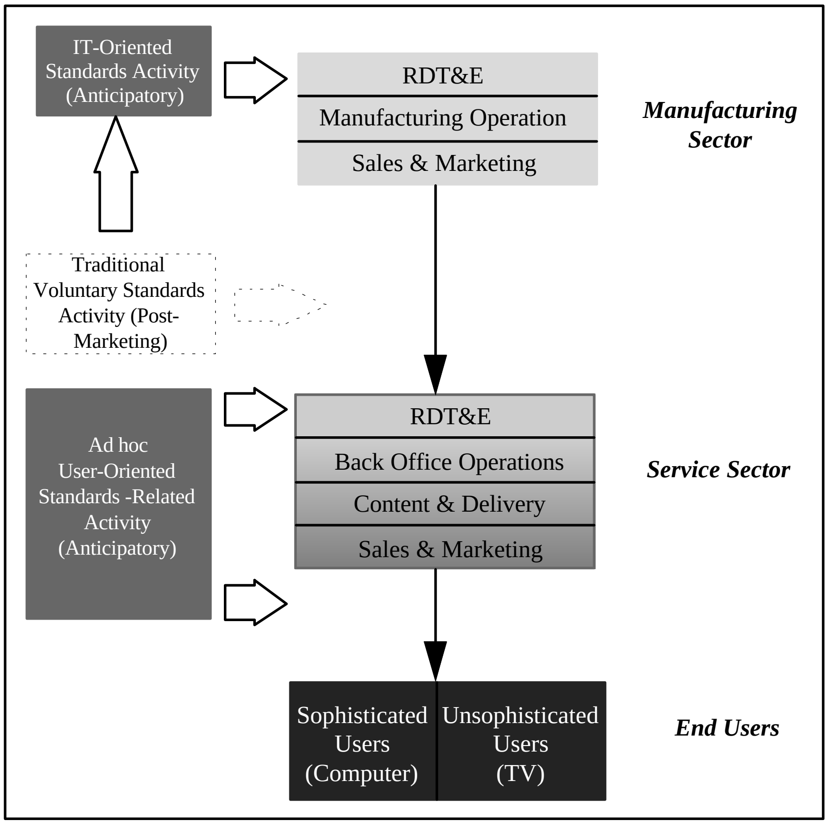
> The thrust of standardization efforts in IT has changed and as a result of a number of developments, such as the ever-increasing range of cross-fertilization between information technology and communications, the major importance of individual PCs, and the resulting need to link them with networks, the growing diversity of satellite equipment and of software, the rising demand of users for compatibility and interoperability, etc. Largely as a result of these developments, some of the traditional approaches which long prevailed in many areas ... are no longer viewed as realistic or economically desirable.
>
> At the same time, the acceleration of technological advances in the IT area has put the standardization system under pressures which may often be contradictory: the production of standards becomes more urgent, but consensus between the interest groups may be more difficult to achieve because of uncertainties and the magnitude of vested interests. Furthermore caution is required to formulate standards which will evolve in line with further development. (OECD, 1991)

This dynamic has given rise to *functional standards* (e.g., Open System Interconnection - OSI) which define performance to be achieved at different layers of technological systems but retain some freedom in deciding how the standard will be met; and *anticipatory standards*, which are developed before the expression of the actual standard and before the onset of competition and its irreversible consequences. This dynamic is seen as formative to the effective development and promulgation of IT standards:

> The relevance of these anticipatory standards will depend on the ability of [their] developers to assess the potential outcome of on-going research in the areas under consideration. For this reason, links between R&D and standardization activities are required, calling for a new generation of committees and organizations at the interface of R&D and standardization. However the anticipatory standards will also contribute to removing user representatives from the standardization process since, by its very nature, an anticipatory standard will anticipate the needs, the demand, and even the very existence of users who do not yet exist.
>
> The ways in which this contradiction between the required participation of users and their de facto absence will be solved will no doubt be decisive for the future of standardization in the IT area. It underlines in any case the magnitude of the new role which may be assigned to governments, as potential clients for new technologies and a representative of the public good and the interests of future clients. (OECD, 1991)

This phenomenon is shown in the upper left of Figure 9-4, as a drift in the locus of traditional voluntary standards development activity (and, presumably, NIST's role in that activity) away from ("upstream" from) the manufacturer-service provider nexus. This interpretation of events is consistent with case study observations that traditional standards organizations lack the focus and the flexibility to meet the needs of service sector firms, and with the emergence of ad hoc collective industry organizations in response to various IT barriers. [113]

Figure 9-4. Emerging Role for User-Oriented Anticipatory Standards Activity



The collective responses, such as those observed in the banking and health care industries, are interpreted as attempts to fill a void for technologically sophisticated, infrastructural requirements. Some have argued that the "ownership" of standards-making processes by users was inevitable as multi-IT vendor procurement increasingly becomes the norm. In this situation the responsibility for compatibility has, *de facto*, been delegated to the user. (O' Connor, 1988) In any event, we hypothesize that these "user-

113 Interestingly, the standards literature makes exceptions to the general observation about a lack of "user" involvement in IT standards processes when it comes to well-organized user industries, such as banking. In discussing the organization of the Banking Industry Technology Secretariat (BITS) in Chapter 8, we asked why these activities were not being undertaken by X9 (the ANSI organization concerned with banking standards). The response: that X9 was too reactive, too slow, and too broadly focused to address the very real needs of the core banking organizations.

focused" collective industry organizations are the institutional solutions to the dilemma posed by the contradictory needs for greater user participation and more R&D-focused, anticipatory IT standards.

There is another potential role for NIST, depicted in the lower portion of Figure 9-4. The integration of the user into the standards process is widely perceived as an important trend. According to some, the ability to accomplish this is required to maintain the legitimacy of the IT standards in the face of rapid change. (Lundvall, 1995) But what is meant by " the users?" Clearly, users include intermediary users, such as service sector providers. Clearly too, these intermediaries are, to a large extent, responsible for determining and attempting to serve end user needs and requirements. But just as clearly, the service sector itself is having difficulty understanding its users' expectations and this translates into barriers of uncertainty and, consequently, underinvestment in IT. So it is at least arguable that NIST should act as a catalyst for efficient standards development — including both content and timing — by facilitating consensus building among the disparate and changing stakeholders.[114] In summary, it appears that NIST has a potentially important role to play in supporting the needs for technology infrastructure in the service sector and that a convenient "entry point" is provided by the various types of informal collective industry organizations that have emerged to facilitate the needs of intermediate IT users.

However, there appears to be growing and widespread dissatisfaction with the institutional framework for standardization. The integration of NIST core capabilities with emerging IT-focused, service sector organizations may provide some support to the evolution of an important process, in a manner that maintains the relevance of the traditional standards organizations (through NIST liaison), while also augmenting their capacity for addressing the service sector infrastructural needs.

From our industry case studies and survey of RJVs reported in Chapters 5-8, we conclude that collective, technology-focused service sector organizations are a good entry point for dialog with industry representatives. These organizations are demonstrably prone to collective action; they are easily

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[114] The National ISDN User's Forum (NIUF), initiated by NIST in the mid-1980s, may contain elements of a model for integrating the perspectives of technology suppliers and users. Whether the definition of "user" in the NIUF context included end-use consumers is unknown. In its early history, the NIUF conducted "user" surveys of service providers attempting to prioritize the ISDN standards most in need of the implementation agreements that the NIUF was established to develop. A different model of "user involvement" is proposed by Alexander (1995) and Naemura (1995).

identifiable; they are responsive; they are articulate spokespersons for pressing technological issues, and they are often involved in activities that are in need of NIST's core technical capabilities.

Across the service sector firms and industries we have studied, collaborative R&D mechanisms are being utilized to acquire the expertise needed to conduct their IT-related research, develop specialized IT capabilities, and to advance IT standards. In the banking industry, traditional industry associations are organizing special technology-focused efforts to rationalize diverse, overlapping, and potentially redundant technical development and standards-related activities. In many cases industry has expressed interest in exploring the potential that appear to require the kinds of expertise that NIST has developed. While NIST could have some role to play in providing specialized infratechnology expertise to these collaborative efforts, it may also be that the other elements of risk (capital intensity, technical risk, long time to market, and appropriability) are not being addressed through these specific collaborative organizations and that NIST could play an additional role in helping industry address such barriers.

Finally, if our assessment of trends in the organization and development of IT standards-related activities is accurate, these collective service sector activities are an important link in the overall development of the technology infrastructure that is increasingly important to the service sector. NIST can engage with these service sector organizations in ways that promote communications between IT users and the traditional IT standards organizations, while at the same time providing much-needed expertise in the analysis and anticipation of IT trends, in the evaluation of competing standards proposals, and in supporting the solution of other important cross-cutting technological issues that are stifling IT development and implementation in the service sector.

Such an orientation is consistent with the recently articulated strategic plan of NIST's new Information Technology Laboratory (ITL). ITL's strategy focuses on the development of measurement tools for impartially measuring IT products so that developers and users can evaluate how products perform and assess their quality. The strategy emphasizes involvement in early phases of standards development and specification development in advance of the formal standards process; support of informal standards groups (including industry consortia and professional societies) in defining and managing standards in a more precise and robust manner; and selected involvement with formal standards organizations where NIST's contribution can be significant.

9.4 POTENTIAL NIST RESPONSES: CROSS-CUTTING TECHNOLOGICAL ISSUES

We have described a broad need for technology infrastructure and what we perceive as a trend toward greater service sector responsibility for instituting that infrastructure. We believe that NIST clearly has a role in supporting that process. This section discusses the cross-cutting issues that affect the development and implementation of technology in the service sector. In some cases familiarity with various NIST programs suggests approaches to persistent, cross-cutting issues. In other cases, no programmatic model suggests itself.

Before discussing issues, it appears that there is a “cultural” affinity between the needs of the service sector and the general mission of NIST that bodes well for programs aimed at supporting the service sector. Besides belonging to the (public) service sector itself, one of NIST’s primary missions is the support of national and international standards. Due to their position in the value chain, and specifically due to their general status as technology users, the service firms are natural allies in the development of timely, widely adaptable standards. Generally speaking, service sector firms prefer multiple sources of supply for the technology intensive assets they acquire. Effective standards are an important way to increase the supplier base.

We perceive an additional affinity rooted in the nature of the typical service sector R&D function. Service sector technology managers are predominately oriented to the test & evaluation facets of the larger technology development process. To the extent that NIST’s core competence lies in the development of definitive test and evaluation methods, the general needs of the technology-based service sector may closely match this expertise.

Against the background of a perceived “cultural fit” with the service sector, there are three over-arching technology issues that an effective program of technology support should address. They are:

- Industry and technology convergence
- Service sector-customer interface
- System interoperability and security.

These broad issues are considered in turn.

The issue of convergence has two aspects. The first deals with the uncertainty that affects service sector industries. The second aspect of uncertainty is that experienced by consumers. In the three industries analyzed in-depth for this report, technology "roadmaps" were unavailable. Not only would such road maps (and the process that produces them) facilitate the objective policy analysis of industries and firms (for example in the form of understanding and industry or a firms distance from a potential technology "frontier"), but it appears that if properly developed, maintained, and diffused, these could reduce the level of uncertainty that afflicts technology managers, and almost certainly positively affect the degree of technology underinvestment. The externalities associated with such an undertaking alone suggest a "public" role. To be useful, such road maps would have to be widely shared, so their benefits would far exceed those appropriable by any individual company. Moreover, the nature of industrial and technological convergence is such that, to be useful, "technology road maps" would need to cover numerous industries (horizontally and vertically). In addition, without some "honest broker" involvement, such an undertaking would be vulnerable to "capture" by narrow proprietary interests.[115]

Whether such road maps represent a response to technology-specific market failures or infratechnology weaknesses will depend on the breadth and maturity of the technology covered. It appears that the generic research efforts supported by NIST's Advanced Technology Program often involve the development of a road map specific to the group of firms involved. On the other hand, the perception that security-related standards are critical to the future of all three case study industries suggests that the coordination of the relevant technology components, trends, and responsibilities embodies infrastructural requirements spanning many service sector industries and their technology suppliers. Such economics of scope increase the ranking of the underlying infratechnologies in terms of economic importance, and therefore imply a high priority for NIST's ITL.

Another facet of the uncertainty that service sector firms face is rooted in the uncertainty about customer preferences. While the analysis for this report did not include customer survey information,

[115] This last point has important implications for the success of the proposed undertaking. Perhaps its success is related to the extent to which the largest, most vested companies would participate in the process of developing a widely accepted technology roadmap. Such "privileged groups" often account for the success of collective organizations. (See Olson, 1965) While the involvement of large, diversified companies might, therefore, contribute to the success of the undertaking, sound public policy would have to control any opportunistic behavior on their part. This is a role for which NIST is well-suited to the extent that the same dynamic is present in the standards-formulation process.

introspection and observation suggests that "the fog" facing consumers is far thicker than that facing the professional technology managers interviewed for the case studies presented.

The "road map" concept could form an element of the public education function that calls out to be addressed (or at least analyzed). We are not suggesting here that "road maps" are central to the demand side of the convergence problem. But we do believe an effective program to support the technology-based service sector must address the demand side of the market failures problem through some effective public information approach.

It does seem clear from the case studies that the supply side of the market is often "on -hold" in the face of both high risks and profound uncertainties and, to a large extent, that these are rooted in an even deeper uncertainty arising at least in part from consumer ignorance about preferences in the face of rapid technological change. In the case of health care, at least, the (intermediate) "consumers" (the physicians and related care providers) are by no means ill-equipped to understand the issues and the potential costs and benefits of greater technology implementation. Yet even there, industry representatives perceive a certain lag in the face of the inevitable adoption of greater and greater levels of technology. Perhaps this case suggests that even where adequate information is accessible, sophisticated (intermediate) consumers are reluctant to incorporate technology to an ever greater degree in the absence of methods to validate its effectiveness or its compliance with other, systemic requirements of service provision. In either case, effective support for technology-based service industries appear to require a focus on users as well as providers of services.

To be most effective, a NIST program to support service sector technology must address a second overarching issue. In each of the case studies the design, development, implementation, and interoperation of technical customer interfaces was seen as paramount. That is, as IT is increasingly used by the service sector to provide service content and delivery, the importance of making these interfaces far more "user friendly" (appealing to the all types of users), reliable, standard, and secure is apparent. And while the design and development of such interfaces may be largely a private sector responsibility, evaluation methods and techniques for assessing the quality of customer interfaces has important "public" aspects and could yield benefits across the service sector in terms of hastening customer acceptance.

The last overarching issue that needs to be incorporated into an effective program to support service sector technology concerns the interoperability of forthcoming, current, and vintage IT software, components, and systems. Often referred to as “the legacy problem,” it is so widespread and costly, that any attempt to bolster the technology infrastructure of the service sector must address the issue. Clearly there are common problems in this regard within the same industries and, more than likely, there are common problems across industries. But to the extend that these common problems are being addresses individually by firms, or by industries where inter-industry solutions are possible, extra transactions costs are being incurred and less technology is therefore being acquired and implemented.

Familiarity with some NIST programs suggests the possibility of establishing a “test bed” that could serve as an initial service sector support program. Such a program might entail a cooperative effort on the part of IT manufacturers, software producers, and service sector providers. Some representative “mix” of hardware and software systems would comprise the physical assets of such an undertaking, and NIST’s IT test and evaluation capabilities might be brought to bear in support of critical technical issues.[116]

9.5 POLICY ANALYSIS IMPROVEMENTS: LESSONS LEARNED

Based on the investigations undertaken for this report, our experience with economic tools and databases, and our retrospective appreciation of issues not sufficiently covered, in this final section we recommend important areas for additional research in support of NIST’s strategic planning in support of the service sector.

First and foremost, additional case studies are in order. In depth case studies are the only route to gaining the level of detailed understanding needed by NIST to support investment choices. Additional case studies would undoubtedly lead to an improved conceptualization of the role of the technology infrastructure in the service sector. For educational and public communications purposes an improved conceptual model of NIST’s role in supporting the service sector could be very important.

The “granularity” and homogeneity needed for the comparative case study analysis of industries would be improved by the cost-effective development of industry specific technology roadmaps. Useful

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[116] Interestingly, in the banking sector, IT consulting firms have established roughly similar organizations to promote the potential for integrating all manner of new IT capabilities. See, for example Andersen Consulting’s *Financial Ideas Exchange,* www.ac.com/topstories. What we propose is a test bed that addresses the fundamental problems caused by continuous upgrading of IT.

approximations of technology roadmaps can be derived from patent data. To be most useful in support of service sector-focused NIST planning efforts, patent-based analysis should proceed from the development of 2 conventions: i) a consensus patent-based definition of information technology; and ii) a consensus patent-based definition of “infratechnologies.”

Another important area of research in support of NIST’s service sector-focused planning should be directed to the theory and application of the concept of market failure. In our judgment, discussion of market failure is rarely undertaken from the perspective of the buyer. An improved understanding of the concept or market failure from a buyer’s perspective would help clarify important issues and lead to better applied analytical tools.

Such tools are another important concern. For case studies of the quality (in terms of focus and depth) required by NIST, it would be very useful to develop “rule of thumb” metrics (not unlike the Hirshmann-Herfindahl Index used as an applied microeconomic analysis device in support of antitrust policy) that provide useful, though imperfect, insights under circumstances of relatively sparse industry information. Relatedly the development of a standard, easy-to-use methodology for generating estimates of IT underinvestment based on readily available accounting information would be very useful and could support priority ranking of industries for infratechnology support. In the conduct of case study surveys, it was often difficult to establish a baseline of information from which to derive underinvestment estimates. Given that income & balance sheet information is generally available, properly developed it could prove very useful in the conduct of important, but time-constrained, discussions with technology managers.

Finally, to the extent that improved statistical estimates of the degree of underinvestment in the service sector are warranted, four areas of further research would add depth to the quantitative analysis contained in this report. First, a methodology aimed at formulating frontier production functions could prove more insightful and possibly allow a tighter integration between firm-level statistical analysis and case study methodologies. Second, broader and deeper analysis of the role of RJVs in standards-related activities across the service sector would provide additional insight to the work reported her which focused on just one of the service sectors — communications services. Third, it would be useful to improve statistical models of service sector productivity by the addition of components that address the competitive impact of standards-related activities.

Fourth, the above models and hence public policy would benefit greatly from better characterization and measurement of the several private and public elements making up service sector technologies, as well as the interactions among these elements. It is the respective economic roles of these private and public technology elements and their complex interactions that create market failure and thereby lead to a need for a public policy response.

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