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# INFORMATION AND COMMUNICATIONS TECHNOLOGY IN CHRONIC DISEASE CARE: WHY IS ADOPTION SO SLOW AND IS SLOWER BETTER?

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**ABSTRACT**

Unlike the widespread adoption of information and communications technology (ICT) in much of the economy, adoption of ICT in clinical care is limited. We examine how a number of not previously emphasized features of the health care and ICT markets interact and exacerbate each other to create barriers for adoption. We also examine how standards can address these barriers and the key issues to consider before investing in ICT. We conclude that the ICT market exhibits a number of unique features that may delay or completely prevent adoption, including low product differentiation, high switching costs, and lack of technical compatibility. These barriers are compounded by the many interlinked markets in health care, which substantially blunt the use of market forces to influence adoption. Patient heterogeneity also exacerbates the barriers by wide variation in needs and ability for using ICT, by high demands for interoperability, and by higher replacement costs. Technical standards are critical for ensuring optimal use of the technology. Careful consideration of the socially optimal time to invest is needed. The value of waiting in health care is likely to be so much greater than in other sectors because the costs of adopting the wrong type of ICT are so much higher.

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## I. Introduction

The information and communications technologies (ICT) that have dramatically changed the way we work, interact, and entertain ourselves also offer tremendous opportunities in clinical care. Potential applications of ICT include remote surgery, transmission of radiological images, interactive video visits, and continuous remote analysis of self-monitored data. Chronic disease management can be greatly improved from the use of ICT given the clinical importance of continuous monitoring and adjustment of care (Shea *et al* 2002). For example, health care providers can have real-time access to patients´ blood sugar measurements to adjust medications and offer advice on lifestyle changes. Such care potentially improves short-term health outcomes and prevents long-term complications. In an era of data beamed to personal digital assistants and spreadsheets attached to e-mail, the technological requirements for receipt and analysis of such biometric data are comparatively small (Starren *et al* 2002).

While many commentators have heralded the great potential of ICT in health care (Goldsmith 2000; Kassirer 2000; Lehoux *et al* 2000; White House 2005), others have bemoaned the backwardness of health care and history of unmet expectations with regard to ICT (Kleincke 2000, Ortiz & Clancy 2003; Brailer[A] 2005). Recently, ICT has been lionized as a potential cure for our health care crisis (Newshour with Jim Lehrer, February 8, 2007). While ICT adoption has been disappointing in several parts of the economy, for example in many business-to-business firms (firms whose main customers are other businesses), there is no industry that as a whole seems to lag as far behind as health care (Shortliffe 2005). The most frequently cited and celebrated form of ICT for almost two decades – the electronic medical record (EMR) – is used by only 23.9% of physicians in the ambulatory care setting, and only 5% of all hospitals for computerized physician order entry (Jha et al 2006).

Why do we see so little adoption of ICT by health care providers, especially hospitals? Some very obvious obstacles include a general lack of demonstrated cost-effectiveness of ICT (Whitten et al 2002), which limits insurers' willingness to reimburse for the use of the technology. Furthermore, without direct reimbursement, few providers are prepared to take on the financial risk of adopting new technologies (Cutler, Feldman, and Horwitz 2005). The extent of behavioral change involved in technology adoption also affects both the rapidity and extent of adoption (Hall 2003). Some innovations in medical care, such as the switch to an EMR involve major behavioral changes and potentially imply temporary efficiency losses. Because medical errors can have severe and irreversible consequences, errors made in the transition to new technologies are also less tolerated than in other sectors. Finally, there are significant legal issues concerning adoption such as licensure, liability, malpractice, confidentiality and compliance with the Health Insurance Portability and Accountability Act (Kuszler 1999; Spielberg 1999; Stanberry 2000; Gottlieb et al 2005).

In this paper we examine how several not previously emphasized features of the ICT and health care markets *interact* and *exacerbate* each other to act as barriers for adoption of ICT in clinical care. Adoption of ICT is generally plagued by problems of high switching costs, technical compatibility in the system(s) of IT, and low product differentiation. In health care, these adoption problems are compounded by the many interlinked markets across payers, providers and consumers which produce a significant mismatch in the financial incentives for adoption. The heterogeneity of consumers with regard to their needs, ability and motivation to use ICT is greater than in other industries. In particular the motivation and ability to use ICT is likely to vary widely across chronic diseases and among patients with the same disease conditional on age, disease severity, and socio-economic status. The greater heterogeneity raises the demands for the interoperability of the ICT systems for information storage and exchange and consequently the costs of such technologies. The greater heterogeneity also raises the costs of replacing technologies, which may effectively lock patients and providers into suboptimal technologies. The fact that decisions to adopt ICT are not easily reversible raises the bar for the technological requirements for both hard-and software in clinical applications.

We also examine the important policy questions of *what* it will require to achieve adoption of ICT in health care and *when* adoption of ICT ideally should take place. To arrive at interoperable ICT systems, a set of specific communication and technology standards in health care are needed. Such standards need to allow systems of ICT to "speak to each other" to facilitate a socially optimal use of technology. What should be the principles guiding the development of such standards? What should be the process for setting them? Who are the stakeholders, and what role should they play? Because decisions to adopt ICT in health care are not easily reversible it is also crucial to consider the optimal pace of ICT adoption given the uncertainty about its value. Too early adoption of ICT may not be socially optimal as the health care system is likely to be stuck with the technology once adopted.

In our analysis we take a societal perspective to determine how we can make the most cost-effective use of health care ICT to benefit society. Others have considered the potential role of ICT in health care and in the economy more generally (Danzon and Furukawa 2001), the health and economic benefits of ICT in health care (Hillestad et al 2005), and the role of standards to accomplish such benefits (Halamka et al 2005; Brailer[B] 2005). The potential of ICT to affect quality of care has also been considered, and it has been suggested that quality improvement itself should be the primary motivation for adopting ICT as opposed to direct cost savings (Goodman 2005; Taylor, Manzo, and Sinnett 2002). Our analysis, however, highlights how a number of not previously emphasized features of the health care and ICT markets create barriers for the usual economic incentives to adopt technology that benefit consumers. It also discusses how standards can address these barriers and the key issues to consider before investing in ICT. While our analysis focuses on the role of ICT adoption to support chronic disease care, many of the analytical insights presented apply to health care ICT more generally.

The structure of the paper is as follows. Section II briefly discusses information and communications technology in health care and its potential to alter and improve clinical care, especially in the context of chronic diseases. Section III looks at the issue of technology adoption, first in the standard competitive market and secondly in the special ICT market. Section IV then considers the unique features of the health care market in regards to barriers for ICT adoption, and how these features interact with the special features of the ICT market to exacerbate these barriers. Section V delineates the principles that should guide the design of ICT standards to ensure an optimal use of ICT, the minimum requirements for such standards, and the process of setting standards. Finally, section VI discusses the socially optimal timing of investments in ICT. Section VII concludes by summarizing the key insights presented on how adoption of ICT in health care can be achieved and when the adoption ideally should take place.

## II. Information and Communications Technologies in Medical Care

The use of ICT in the practice of medicine is generally referred to as telemedicine and medical informatics. While the terms are often used together, they are actually distinct. In formal terms telemedicine is defined as “the use of electronic information and communications technology to provide health care when distance separates the participants” (Institute of Medicine 1996; Grigsby and Sanders 1998). Telemedicine therefore comprises all forms of electronic communication, including interactive video, the phone, the fax, text messages and images transmitted through cell phones, and all types of web-based communication. Any communication between patients and providers and among providers, whether real-time or “store and forward”, is covered by the definition of telemedicine. The National Library of Medicine (2001) defines medical informatics as “the field of information science concerned with the analysis and dissemination of medical data through the application of computers to various aspects of health care and medicine”. The central difference between medical informatics and telemedicine is the integration and analysis of electronic data. When a primary care physician (PCP) sends an e-mail to the patient with the result of a clinical test this is an example of telemedicine only, whereas any form of computer-assisted and initiated analysis of electronic data to support health care delivery is an example of medical informatics at work.

A taxonomy of four categories roughly describes the many potential applications of ICT for chronic disease care. From the lowest to the highest level of technology, they are: 1) technologies that support patient self-care and education, 2) patient-provider and provider-provider communication, 3) electronic data storage and data sharing across providers, and 4) technologies that combine all of the applications above.

In the first category, both medical devices for self-monitoring and interactive web sites for education on chronic diseases represent long-standing use of ICT. Numerous firms, including most insurers and some pharmacy benefits management companies, maintain web sites to support people living with chronic conditions (e.g. Medco Health www.medcohealth.com, accessed January 31, 2007). Through this medium, patients can enter and store personal health data, and the site provides summary reports and simple graphics to inform about disease status and offer advice for enhanced self-care. Medical devices to support self-care of chronic diseases also exist in a large variety. For instance, an annual guide for all people living with diabetes, the *Diabetes Forecast*, listed in January 2006 eight different software packages that accept and analyze data from blood glucose meters.

The very hallmark of telemedicine, communication by the phone, videoconferencing or e-mails between patients and providers and between providers, falls in the second category. Disease management of heart disease brings a number of examples of how such means of communication potentially bring significant clinical and economic benefits (Bondmass et al 1999; Jerant et al 2001). In a population of patients with congestive heart failure (CHF), Roglieri et al (1997) for instance examined the effect of a weekly phone call from a nurse obtaining information about the patient's health by administrating a standardized health questionnaire. The nurse also sent targeted educational mailings and potential alerts to PCPs depending on patients´ responses. They found a reduction in readmissions for all subjects of 63% over a one-year period together with lower average length of stay and use of the emergency room. In a more advanced telemedicine application in the management of CHF, the use of a two-way interactive video technology for home care reduced hospital admissions by 82% and use of the emergency room by 77% (Chetney 2003).

In the third category, the EMR probably represents the most well-known example of software that provides for communication and data integration among providers. The Veterans Health Administration (VA) has been a leader with an advanced system of electronic medical records linking pharmacy, laboratories, and all medical providers (Perlin, Collins and Kaplowitz 1999). The system has been considered instrumental for the impressive outcomes achieved for people living with diabetes and other chronic diseases in the VA (Sawin et al 2004). In economic terms, the system has increased productivity by nearly 6% per year since it was fully implemented in 1999 (Evans, Nichol and Perlin 2006). Another example of an integrated delivery system adopting the EMR is Kaiser Permanente (2002). Physicians in this network can order patient medication online and receive clinical results from laboratory and radiology departments at desktop computers in their own office or in the exam room. Other professionals in the network such as nurses and pharmacists can also lock into the system and read up-to-date clinical information about all patients in the network. Through a company website, the insured population can search for health information and request appointments, refill prescriptions or send questions to a nurse or pharmacy. There are few economic evaluations of the potential of the EMR, yet recent evidence seems to suggest that the value to the individual health care provider can be substantial. In an evaluation of the integrated delivery network of Brigham and Women´s hospital and Massachusetts General Hospital, the net financial benefits of the EMR was estimated at $86,4000 per provider over a five-year period (Wang et al 2003). The cost-savings were primarily attributed to lower drug expenditures, improved utilization of radiology tests, enhanced capture of charges and reduced billing errors.

The most advanced form of ICT in chronic disease care – provider and insurer software that continuously integrates and analyzes provider and self-monitored patient data coupled with communication technology, represents the fourth category. The opportunities for rapid, effective and inexpensive interventions by providers and patients seem endless. Computers that automatically and continuously monitor patient status, treatment protocols and care provided is not technically an unrealistic example of how ICT can deliver entirely new forms of care in the future. The technology has so far been applied to continuous remote clinical monitoring with significant benefits to patients and payers. In management of hypertension, home blood pressure monitoring has been effective in controlling blood pressure, diagnosing “white coat” hypertension, targeting organ damage, improving prediction of hypertension-related morbidity, improving patient compliance, and allowing faster therapy adjustment (Asmar and Zanchetti 2000; Artinian et al 2001). The technology is also used by major health insurers to ensure an optimal use of pharmaceuticals among its members. By applying a “clinical algorithm engine”, Aetna´s MedQuery$^{SM}$ program for instance searches through pharmacy, laboratory, and medical claims data, which the software then combine with demographic information to identify problems and gap in the use of medications among its members (www.aetnapharmacy.com, Accessed March 15, 2007).

All the examples provided of ICT in chronic disease care potentially carry one or more societal benefits from better health outcomes, lower direct use of health care and/or lower indirect costs. As evident from the CHF program, fast and frequent communication between patients and providers allow for better monitoring of patient adherence to disease management. The evidence from remote monitoring of hypertension illustrates how frequent collection of data allows the provider to act more quickly and adjust treatment regimens. The experience of the EMR in the VA program demonstrates how assembly of information from different sources, such as laboratory tests, hospital, and self-monitored data allows for a better overview of patient status. In general, the wider and more rapid dissemination of information and data analysis, presentation and interpretation allow many more health care professionals to provide quick input to the chronic care of the patient. Additionally, because ICT may reduce the time needed for patient self-care, a lower non-financial benefit, “compliance” may be enhanced with better health outcomes as a result. Equally important such improvement in short-term outcomes, e.g. a lower blood pressure or cholesterol level, may reduce the risk of long-term cardiovascular complications and premature death (Lloyd-Jones et al 2002).

The cost-savings demonstrated from better management of drug expenditures and use of radiology tests by use of the EMR also indicate that lower direct resource use may be possible. The example of quicker detection and prevention of acute problems among individuals living with heart disease also lowered costs by avoidance of emergency room visits and hospitalizations. A potentially very important, yet unmeasured, cost-saving aspect of ICT relates to time spent on patient care. For instance, patients and providers can save time through avoidance of phone tag. Physicians and nurses can save time in collecting and disseminating information by avoiding repeated handwriting, photocopying, searching paper files and deciphering handwriting. Case management economies of scale may exists as nurses can communicate much more efficiently with patients than through in-person office visits. Coordination of care may also be less time-consuming given the ability to communicate quickly all relevant information in easy to digest form to specialist consultants and other providers while at the same time improve the quality of care and hence treatment outcomes. The Institute of Medicine (2003a, 2003b) recently described in a series of reports how many providers communicate inefficiently with each other with implications for health care quality and outcomes.

For the individual provider or hospital, the initial cost of adopting and implementing technologies such as the EMR may appear prohibitive (Burton, Anderson and Kues 2004), and the economic savings from avoided hospitalization and reduction in unnecessary tests may not benefit them financially. However, from a societal perspective, and in the payer community, ICT offers potential for lowering direct resource use both in the short and long-term through avoidance of hospitalizations and emergency care and improved intermediate outcomes. In a recent estimation of the potential health and financial benefits of health care ICT, Hillestad et al (2005) estimated that use of the EMR in prevention and management of asthma, CHF, chronic obstructive pulmonary disease and diabetes could result in $139 billion in total savings per year, a total of 400,000 fewer deaths, and 42 million fewer days lost from work, if fully implemented and utilized. Walker et al (2005) evaluated the financial benefits of completely standardized health care ICT across providers (hospitals and medical group practices), independent laboratories, radiology centers, pharmacies, payers, public health departments and other providers. Their most optimistic projection implies net financial savings of $77.8 billion per year if fully implemented on a national scale.

Finally, the greatest societal benefits may accrue directly to people living with chronic diseases, their families and their employers, rather than payers or even providers. The reduction in indirect costs from less travel time, less waiting time, and less time off work can be considerable – both for patients and family members who accompany them during hospital and office visits. All of the examples of telemedicine described potentially imply less time needed for patient-provider interaction. As evident from the examples of ICT in management of CHF and hypertension, software that allows for quicker and more efficient disease management also holds the same time saving potential through avoided office and ER visits.

Overall, ICT applied to chronic disease care offer the *potential* of “more for less” from a societal perspective. The technology may make it possible to produce more health without increasing the cost per patient treated or alternatively generate the same health outcomes at a lower cost. It is also possible that the technology can generate previously unattainable levels of health. However, the health economic potential of ICT will not necessarily result in lower total health care expenditures (Goodman 2005). Rather, because it is now cheaper to achieve a given amount of health improvement, it may be worth buying so much more health improvement that total health care spending increases. In general, while technological improvement can allow us to provide the same level of health at a lower cost, it can potentially also make it worthwhile to spend even more resources on health care to greatly improve health (Weisbrod 1991). Indeed, this is one very reasonable interpretation of society’s growing health care expenditures (Glied 1997; Cutler and McClellan 2001). Of course, if payers only consider the cost of providing such care and not the benefits provided, the value of many ICT applications will be highly uncertain (Cutler, Feldman and Horwitz 2005). The great heterogeneity of ICT – from interactive web sites to the completely integrated EMR – also implies an equal variation in the value of the technology to society. Technologies that simply shifts costs across providers or among providers and payers do not offer “more for less” and carry no value to society.

## III. Technology Adoption

In standard competitive markets, economic forces automatically push for adoption of technologies that are socially beneficial. In this section, we first briefly summarize the adoption that economic theory would predict of technology used as input to production of goods and services in the standard competitive market. Secondly, we contrast this adoption pattern with the adoption patterns that can be expected for ICT, both for the type of ICT used as input into the production of goods and services and the ICT used directly by private consumers.

### *Standard Market: Adoption of Technology*

In a standard competitive market, consumers who comparison shop and "vote with their feet" provide the pressure for lower prices, higher quality and more desirable products. Producers have an automatic incentive to adopt a technology that lowers production costs as they can charge lower prices and attract more consumers. Consequently, even if a technology requires a substantial investment, implementation or transition costs, a firm will make that investment if there is a net reduction in production costs. For example, in the last decades the banking industry has spent enormous sums transferring existing data into new information systems and providing on-line financial services to private consumers and companies (Cavallo and Rossi 2001).

In general, consumers will chose a higher price and higher quality product over a lower price, lower quality product if they find the added value greater than the added cost. Again, firms have an incentive to adopt a technology that increases quality if the additional amount consumers are willing to pay exceeds production costs of the new product, including adoption costs. Of course, uncertainty about consumer preferences and risk aversion by firms somewhat reduces this optimal response by firms. Finally, if an entirely new product is created, consumers will choose to purchase it if its value to them exceeds its price. Once again, firms will have an automatic incentive to adopt the technology to produce that product if consumers' willingness to pay exceeds their total production costs, including the costs of technology adoption.

More generally a standard perfectly competitive market with no increasing returns to scale will result in every firm adopting the amount and type of technology needed to operate in the most efficient way. In the short-run, firms increase profits by investing in new technology and producing more efficiently. In the long run, inefficient firms are priced out of the market. Thus, the optimal mix of labor and capital is achieved through exit and investment in new technology. When there are economies of scale, as when there are large fixed costs, firms still have every financial incentive to adopt technology that will provide additional profits. However, new technology may alter the optimal scale of the firm adopting the technology. For example, technological advances in the retail sector, such as inventory management software, are difficult for small firms to adopt. Larger retailers adopt the new technology and consequently enjoy a cost advantage.

Through exit and entry and mergers, the retail market has become more concentrated (Hosken and Simpson 2001).

*ICT Market: Adoption of IC Technology*

A critical issue in technology adoption is whether or not the technology interacts with the technology of other producers or consumers. For example, to be valuable, a travel agent's software must interact with the computer systems of airlines and other agents in the travel industry. This is known as a network effect (Rohlfs 1974; Farrell and Saloner 1985; Katz and Shapiro 1985; Katz and Shapiro 1994; Shy 2001). The importance of network effects varies from case to case, but potentially they slow down or completely halt the adoption of a new technology if they are large enough. In general, the private benefits consumers derive from joining a network do not include the benefits that accrue to other existing consumers in the network. This may imply that the private marginal benefits are smaller than the social marginal benefits, and that the equilibrium network size as a result is smaller that the socially optimal network size. Network effects can also influence the optimal scale of the firm by providing an incentive to bring more or all producers into one firm, so that the network effect is internal to the firm.

In contrast to the importance of economies of scale in the standard competitive market, the ICT market is primarily driven by economies of networks (Shapiro and Varian 1999). Networks, in this context, are understood as both physical networks such as telephone or airline networks and virtual networks such as networks of compatible fax machines or networks of compatible software programs for personal computers. The value of networks fundamentally depends on the number of existing users in the networks. This key economic characteristic is also known as network externalities and demand-side economies of scale. Network externalities are normally positive in the sense that when one consumer joins a network, the network gets bigger and all existing consumers in the network – whether companies or private consumers using ICT – benefit from this expansion.

An additional, and intrinsically related, principle of economies of networks is a phenomenon known as positive feedback (Katz and Shapiro 1994). Positive feedback is based on the premise that large networks are more attractive to users than smaller ones and that customers seek the network they *expect* to offer the best connection. This implies that expectations of a network effect may eventually lead to the realization of that network effect. For instance, in the early days of the market for fax machines the value of existing fax machines increased as one new customer bought a fax machine and thereby joined the network. Furthermore, other potential customers were now more tempted to buy a fax machine and join the network as the value of the network had increased. This phenomenon, known as Metcalfe´s law (Shapiro and Varian 1999), mathematically states that the value of a network goes up as the square of the number of users. Positive feedback is driven by the "bigger is better" aspect of networks and positive feedback drives the network externalities.

The concept of positive feedback is crucial for understanding the adoption of ICT. The dynamics of positive feedback imply that ICT manufacturers with large market shares are likely to get even bigger while smaller manufacturers are likely to eventually disappear. This may imply dominance of a single firm with little diversity in the technologies available. A number of historic examples exist in the ICT market where manufacturers have competed for the same market characterized by strong positive feedback and only one of them have emerged as the winner (Katz and Shapiro 1994; Shapiro and Varian 1999). A case in point was the replacement of Atari with Nintendo as the preferred home video game back in the 1980s. In 1985 Atari dominated the market for home video games, and the company had shown little interest in bringing new innovative products to the market. However within a year after launch, Nintendo was the most popular game on the market, and the very popularity of Nintendo attracted more game developers to write games specifically for the Nintendo systems which further increased the popularity of Nintendo systems among the consumers. The positive feedback that occurred with more users enticing more product development, which attracted even more users and more development, illustrates a market dynamic where consumer demand for the “winning technology” drives the choice of technology and network. This also implies that the competing network and technology with the smallest number of users may exit the market completely.

Positive feedback generally implies fewer suppliers and hence less product differentiation due to this winner-take-all characteristic (Katz & Shapiro 1994). While positive feedback can occur in the standard market, such positive feedback rest on supply-side economies of scale, i.e. large firms typically have lower unit costs. As competition sets a limit to the size of market players (i.e. it is harder to efficiently manage large corporations) there are also limits to the benefits of supply-side economies of scale. In the standard market we therefore expect more suppliers and hence more product differentiation than in markets marked by network externalities such as the ICT market. The effect of low production differentiation on the decision to adopt ICT eventually depends on consumers and their user requirements, but in general slower and *possibly* lower adoption of ICT can be expected than for other technologies.

The cost of ICT adoption is also more complicated than the adoption costs of other forms of technology. Aside from the pure acquisition costs, training is frequently needed in how to use the new technology, which may imply significant short-term costs in terms of the time spent away from other productive activity. For the type of ICT where new electronic communication technologies replaces old paper records, old electronic systems, or the merger of existing electronic systems with new systems, there is also the switching cost of such technology adoption. In fact, switching costs are the norm rather than the exception in the ICT market (Shapiro and Varian 1999). Because information is stored, manipulated, and communicated using a "system" consisting of multiple pieces of hardware and software and because specialized training is required for using each specific system, there are switching costs associated with each of these interlinked technologies. Furthermore, when a company has made significant durable investments in complementary technologies that are specific to a brand machine and when these investments have different economic lifetimes there may not be any easy time to start using a new incompatible system. In these situations, consumers face switching costs which may effectively prevent adoption of new technologies.

The cost of ICT, and in particular the switching costs of ICT, also needs to be understood as more than just an economic barrier for adoption. When the costs of switching from one brand of technology to another are substantial, consumers may in fact be locked-in to a specific form of ICT, either at the system or vendor level. Additionally, depending on the industry, the risk of using a new vendor or technology, especially an unproven one, can be huge given the potentially very high costs of system disruption or break-down. Such break-down may imply irreversible damage to the company or individual consumer. Because the decision to adopt a new technology is not easily reversible, adopters of ICT need to think carefully about the added value of adopting the technology far into the future. When there is uncertainty about the future requirements of the technology consumers may be very reluctant to adopt a new technology and this can also halt the adoption process more generally. In summary, when there are substantial switching costs associated with ICT users may be locked into to a specific technology and infrastructure for long periods of time, which may inhibit adoption of new forms of ICT.

Technology compatibility (or interoperability) also plays a much more prominent role in the adoption of ICT than other forms of technology. The value of any information and communication technology is fundamentally linked to the ability to connect through a common technical standard with other electronic means of data storage and communication. From the perspective of an ICT manufacturer a fundamental trade-off therefore exists in developing new products and technologies for the ICT market; should the products be compatible with existing products and thereby accept old performance standards or should they bring about a completely new technology platform that offer vastly superior performance? When new products are compatible with older forms of technology, and thereby allow for their continued usage, the opportunity to drastically improve overall ICT performance will be less than when introducing a completely new technology. However, the costs of adopting compatible technologies will be lower as well. Conditional on the type of consumer, the size of switching costs can be the determining factor for whether adoption of completely new forms of ICT takes place at all. The trade-off basically highlights the conflict that exists when innovative technologies clashes with network externalities and their associated switching costs (Shapiro & Varian 1999). Lack of compatibility represents a unique barrier for adoption of ICT technology, and potentially delays the adoption of vastly superior technology for long periods of time.

Finally, while problems of compatibility can be addressed by common technical standards it is not obvious that these will develop in the competitive market place. In fact, incompatible technologies often compete in a high-stakes winner-take-all battle, where the market outcome can either be a truce with multiple producers, a duopoly with only two competing producers or a fight to death where no technology survives commercially (Katz and Shapiro 1994). A critical element in such competition is the magnitude of the switching costs for each rival technology. A case in point is the AM stereo radio, which never became a success in broadcasting (Shapiro & Varian 1999). Having failed to endorse one stereo standard in the early 1980s, the Federal Communications Commission decided to let the market choose the best standard and hence bring about the next generation of stereo radios. Four rival systems competed for the interest of radio broadcasters and receiver manufacturers, yet the substantial costs of the new AM compatible radios, the uncertainty about the winning technology, and their incremental value to existing radios implied little interest in any of the systems among consumers. The case illustrates that rival, incompatible, technologies can slow down or stop the adoption of ICT completely, and that a new technology must offer significant value-added to initiate positive feedback. The experience also illustrates that ICT adoption may be especially difficult when multiple groups of adopters need to coordinate and agree on a common technical standard.

To summarize, the ICT market has a number of unique features compared to the standard competitive market, which may delay or completely prevent the adoption of beneficial technologies. The main barriers to ICT adoption as compared to adoption of other forms of technology include low product differentiation due to positive feedback and market dominance, high switching costs with resulting lock-in to potentially suboptimal technologies, and lack of technical compatibility of all the different components of an ICT system.

## IV: Health care and the ICT Market

*Interlinked Markets and Bundled Goods:*

It is well known there are many market failures in health care (Arrow 1963; Pauly 1974; Rice and LaBelle 1989; Dranove and White 1987; Aaron 1991). We will only discuss the market failures and structural characteristics of the health care market relevant for the economic incentives to adopt ICT that benefits patients. Indeed, many of the relevant barriers to ICT adoption are not related to moral hazard (the tendency of individuals, once insured, to behave in a way that makes use of health care more likely) or adverse selection (the tendency of those experiencing greater health risks to apply for more health care coverage), the two most commonly stressed market failures in health care. As in the analysis of the ICT market, we examine adoption by firms (providers) and consumers (patients). Provider ICT is understood as technologies that enhance medical care, while patient ICT consists of the various technologies that support self-care and management of chronic diseases.

Most health care services are covered through medical insurance. Thus, any discussion of the economic incentives for technology adoption among patients and providers in the health care market must consider both the operations of the insurance market as well as how insurers and health care providers interact. To make things even more complicated, health insurance is most commonly purchased or provided by either employers or the government. Consequently, there are three interlinked markets in health care: health care services, health care insurance and the labor market (or the political economy). The result of all these complicated linkages is that market forces from consumers to the health care providers are far more indirect and blunter than are the market forces in most industries. The forces must be transmitted through each stage and each stage brings its own transaction costs.

Health care services that are not covered by insurance but purchased directly out-of-pocket are not subject to the same "clunky" market forces but to more direct conventional market forces. Consequently, producers have more forceful and direct incentives to innovate based on consumer preferences. For example, there has been rapid growth in psychotherapy via e-mail and other internet media. Psychotherapy is often not covered by conventional insurance with approximately forty-percent of all mental health care expenditures paid out-of-pocket among the privately insured (Zuvekas 2001). There is even an e-therapy consumer information web site (http://www.metanoia.org/imhs/, accessed January 31, 2007) to provide independent information and help consumers. Another example is the "boutique" medical practices that do not accept insurance and have relatively wealthy clients who can afford to pay for regular health care out-of-pocket (Belluck 2002). Long-term care is also not covered by conventional private health insurance and there is emerging use of "smart technologies" for communications and monitoring of the elderly living alone (Wallace 2003). Finally, out-of-pocket payments in primary care for simple technologies such as e-mail have also seen the light of day, and patients appear increasingly willing to pay for such services (Andrews 2003).

Most health care services, however, are covered by insurance and are therefore subject to the interlinked market forces. For services covered by standard health care coverage, patients cannot demand that physicians provide new services or change the form in which services are provided. Consider what is involved in trying to persuade physicians to substitute e-mail for in-person visits if the physicians are only paid for in-person visits. The usual market mechanism transmits preferences of consumers into incentives for producers through consumers "voting with their feet" or the fear that consumers will vote with their feet. Few patients will decide to switch primary care physicians just for the option to use e-mail. Too many aspects of health care services are *bundled* together in one primary care physician for a perfectly competitive market outcome. More importantly, to the extent that e-mail substitutes for reimbursed services, no physician paid fee-for-service will want to substitute too much e-mail, even as a means of attracting more patients, because of the loss in financial profits. The phone is an excellent example of how payment drives the use of technologies. Physicians generally hesitate to use the phone in today's practice of medicine as a phone call potentially substitutes for a reimbursed in-person visit. Some use of the phone does occur, in particular for follow-up visits and emergency situations (Spielberg 1998; Car and Sheikh 2003) and in some medical specialties more than others. However, limited use of the phone to situations where the quality of the care is otherwise compromised or the opportunity cost to the patient is excessive stand in sharp contrast to its widespread use in the rest of the economy.

In principle, the market forces that are at work in the health care system should work through insurers. In order to persuade the insurer to change payment policy, and hence persuade providers to adopt ICT, an individual would lobby the insurer or simply change insurer. But due to the highly bundled nature of health care insurance, switching insurer has a myriad consequences and it is difficult to imagine consumers able to effectively target such a small and narrow piece of insurance as payment for e-mail for instance through this mechanism. Additionally, many individuals with employersponsored insurance only have one or two health plans to choose from, making the option of switching illusive.

Using the example of payment for e-mails, employers could pressure insurers to change their e-mail payment policies if enough employees felt strongly enough about the subject and indeed we do observe market forces at work through this mechanism, such as the push for point-of-service plans. However, the employer motivation for doing this is ultimately rooted in the labor market and the fear of losing employees if they are unhappy with their health care. Since a job is much more than simply a source of health care benefits, employees are unlikely to leave a job merely because their physicians do not use e-mail, and hence simple employee pressure is not likely to initiate adoption. An additional employer motivation for caring about health care benefits is that employee dissatisfaction may lead to lower productivity or lost work days, even if it does not result in employee departure or higher wage demands. If the employer is large enough and cares enough about the availability of health care ICT for employees, the traditional market forces should work as the employer can state a credible threat of switching sales to another insurer. However, given the low use of ICT in health care today it appears that large employers simply do not see these benefits as significant enough to pressure insurers. In addition, many small employers, constituting approximately three-quarters of all businesses in the U.S. and employing one-third of the private sector workforce (U.S. General Accounting Office 2001), have little market power and will be unlikely to have any real leverage in negotiating with insurers.

Government provided insurance, such as Medicare, requires effective lobbying from consumers (as voters) and providers to change government payment policy. As is well known, the political economy favors the preferences of the median voter and is subject to a variety of market failures in the political economy (Congleton 2002). Historical examples do exist of successful political lobbying such as the repeal of the Medicare Catastrophic Coverage Act of 1988 following a hefty chase of the chairman of the House Ways and Means Committee down the streets of Chicago by angry senior citizens (Sparer 1996). However on issues of less fundamental nature, the road from the consumer to the politician to the political compromise and the eventual impact on provider behavior is generally a strenuous one. Health care provider associations, such as the American Academy of Family Physicians and the American Hospital Association, have much stronger means for influencing government policy, and indeed we have seen limited changes to Medicare payment policy for the type of ICT that directly benefits health care providers in rural areas (Puskin 2001).

Private and public insurers will be motivated to provide payment for ICT if its adoption results in sufficient net cost-savings by lowering use of other forms of care. Insurers may also adopt ICT to improve the quality of health care and hence improve patient outcomes. In these cases, there is no market failure. The barrier right now is a lack of demonstrated cost-effectiveness of ICT in chronic disease care from the insurers' perspective (Whitten et al 2002). Even if payment for ICT enhances quality of care, improves health outcomes, and as a result lowers health care costs over the life span of patients, such long-term cost-effectiveness potential is not relevant to many private insurers. Both existing health care payment designs and the usual time horizon for private health coverage prevent many insurers from internalizing the resource savings resulting from the use of ICT. While payment rates in theory should adjust in the long-run to technology driven changes in medical care, any form of payment designed as a fee-for-service is bound to always be one step behind the technological progress (Christensen and Remler 1997). Without significant changes in current payment mechanisms and coverage designs private insurers have good reasons to be more skeptical of the cost-effectiveness of ICT than companies in other industries.

Finally, health care providers may have an economic incentive to adopt ICT if the technology results in sufficient savings of other resources to provide a reasonable rate of return or if they are reimbursed directly for the use of ICT in clinical applications. As for insurers, the problem now is a lack of demonstrated cost-effectiveness of ICT in chronic disease care. In addition, without direct payment for use of ICT, the economic barrier for use of ICT is even higher for providers than insurers, since existing payment forms (predominately fee-for-service) are tied to the volume of services provided rather than the overall health care delivered within a given time period.

The traditional basis of payment in chronic disease care also interferes with ICT adoption (Miller et al 2005; Christensen and Remler 2007). The contrast with the rapid and extensive adoption of other new medical technologies reveals the problem (Gelijns, Zivin, and Nelson 2001). Telemedicine and medical informatics are new ways of delivering care, not simply another procedure. Decisions about adopting another procedure are very different. For example, the MRI was just another diagnostic test and existing payment methods and benefits schemes covered diagnostic procedures. In contrast, repeated monitoring of data and its analysis through software is a new form of "care" that cannot easily be added to existing payment systems or benefits. E-mail, like telephone calls, is another way of providing the same kind of care that is normally provided in an office visit.

The size of the development and implementation costs of ICT can vary from industry to industry, yet they are likely to be particularly large in health care in general, and in chronic disease care in particular. Compared to banking services, health care is much more heterogeneous in the type of consumers encountered and the type of services required. Health care and resource requirements vary immensely across chronic diseases. Moreover, even patients with the same type of chronic disease vary significantly depending on the disease severity, age and socioeconomic status. The development and adoption of the EMR for instance is intrinsically complicated due to clinical complexity and the need to serve many purposes. Implementing a new medical record involves entering existing data from paper medical records, an extremely time-consuming task. If existing data is not entered, then providers must work with parallel paper and electronic records for an extended transition period. Additionally, much of the value of having provider data in electronic form results from integration of data across providers. The magnitude of the network effect can be enormous, yet its realization requires a collective decision to adopt ICT among many providers who may stand to gain very differently from this adoption.

Finally, as in much of health economics, selection really undermines the societal benefits of the competitive process (Newhouse 1994). An insurer does not want to provide a service that disproportionately attracts more expensive individuals. Thus, payment for e-mails that are particularly attractive in chronic disease management can have adverse financial repercussions if they disproportionately attract people with chronic diseases without providing sufficient additional compensation through risk adjustment. Alternatively, payment for e-mail could disproportionately attract relatively young and non-severe patients, because they are more likely to be computer-literate. Thus, the impact of selection on incentives for ICT adoption is ambiguous and clearly depends on the specific form of payment (Christensen and Remler 2007).

In summary, bundling at the health care service level, bundling at the insurance plan level, the many interlinked markets, transaction costs, patient heterogeneity, the traditional basis of payment, and selection interfere with the economic incentives to adopt new ICT.

*Interaction of Barriers to Adoption: ICT Market and Health Care*

The interlinked markets in health care, combined with great consumer heterogeneity, significantly intensify the problems relating to ICT adoption in all markets – low product differentiation, high switching costs and technical compatibility. The usual market framework of consumers and producers in the standard competitive market is much more complicated in the market for ICT in that producers also encompass complementors, information goods producers, systems producers, component producers and infrastructure operators. Facing this vast array of manufacturers is an equally diversified consumer group in health care, including patients of all ages, education levels, and disease severity, a myriad of different types of health care providers using ICT as input to the delivery of health care, including PCPs, hospitals, hospital physicians, and outpatient providers, different insurers (private and government), the insured and those paying out-of-pocket. The many actors makes the question of who will benefit from ICT adoption in health care and who will pay for the adoption significantly harder to answer than in other sectors of the economy. All the barriers identified to adoption of ICT compared other forms of technology needs to be overcome by a highly diversified group of consumers with vastly different needs and resources for adopting ICT. In addition, consumers in health care require very different types of ICT depending on whether they are a patient, provider or payer, and within each of these three general types of consumers there is immense variation in specific needs and requirements for ICT capability. Such high demands for product diversity in ICT stand in sharp contrast to an ICT market equilibrium typically characterized by low production differentiation.

The many actors in health care complicate the issue of switching costs. In addition to patients, providers and insurers, there are the producers of software and hardware and those providing the communication infrastructure. Each actor depends on other actors – directly or indirectly – in the use of the same or associated technologies. Replacement of one or more components of the overall communication and data sharing infrastructure – due to technological change or change in user requirements – implies switching costs for all agents. In addition, patients are different from the typical consumers of ICT who buy and use the technology for reasons of business or pleasure. Not only are patients likely to be older and less savvy in using ICT, which raises the operational requirements for “user friendliness” of any software, but their needs for ICT are also likely to be more disease-specific. One type of ICT will not fit all patients and any change to the operating platform of health care ICT will imply changes, and hence switching costs, to many disease-specific types of patient software.

Overall, there are three major sources of switching costs must be addressed by all consumers before adoption of a new ICT can take place in chronic disease care. First, there is the cost of adopting new durable hardware such as mainframe computers and operating systems to store information and the costs of complementary products such as system management software to manage the information and database itself. The durable hardware may dictate the follow-on products that a customer must buy in order to work with the hardware. Secondly there is the cost of information storage in databases and the cost of moving information from one database to another, including the cost of additional data storage (e.g. old medical records that need to be store for legal reasons). Consumers, such as hospitals and insurers, with massive information encoded in specialized formats need to spend the time and money of transferring such data to new systems. Furthermore, switching costs tend to rise with time as more and more information is stored in historical databases. Any new system of information storage makes them vulnerable if and when they require new hardware or software to work with the data. In fact, computer software programs and data files represent a critical component of format-specific information as any system in which information is collected over time in specific format cause lock-in to grow over time. Third, there is the cost of the training involved in using the new ICT. This training is often brand-specific and considerable additional time will be required to learn to work with a new technology with even the same level of efficiency. With brand specific training switching costs are likely to rise over time as personnel become more and more familiar with the existing system.

A key challenge in health care for adoption of new ICT is how to ensure a network of a size that overcomes the collective switching costs. Adoption of new ICT may be further complicated when switching costs stem from durable complementing assets, e.g. one person's investment in a network is complementary to another person's similar investment. As described, when such investments have different economic lifetimes and when they are brand specific, then there may not be an easy time to start using a new incompatible system. Equally important, switching costs are non-linear (Shapiro & Varian 1999). For instance, persuading 5 hospital networks to switch to a new IT platform is more than 5 times as hard as getting one hospital network to switch, yet all 5 of the hospitals need to switch as no single hospital wants to be the first to give up network externalities. Because of the many different consumers of health care ICT it will be highly difficult to coordinate a switch to a new, incompatible, technology.

Finally, given the interlinked markets technical compatibility will be paramount. To fully utilize the potential of ICT, patients will need to be able to communicate and exchange data with providers and payers, and providers will need to be able to communicate with other providers and payers, and payers need to communicate with each other. Each consumer will have different needs for information and data exchange and the ICT will need to use a technical standard that accommodates all these different needs.

## V: Technology Standards in Health care

Common technical standards have the potential to facilitate and accelerate the adoption of the most optimal ICT (Farrell and Saloner 1985; Hammond 2005; Pedersen and Fomin 2005). First of all, standards play an important role for enhancing compatibility, and hence generating greater value to users by making the size of the network externality larger. The 3½ standard for computer disks, for example, sidestepped the need for data conversion from one format to the other and hence made easy data sharing across a larger network possible (Shapiro & Varian 1999). By enhancing the ability to share data, the 3½ standard also attracted more consumers, which further expanded the network externality. Secondly, technical standards also reduce the technology risk faced by consumers as they are less likely to end up stranded with an incompatible technology (Katz and Shapiro 1994). A standard endorsed by many stakeholders can increase the credibility of a technology, and through adoption and expanded network externalities, the standard may in fact become self-fulfilling. By the same token, consumer confidence and fear of stranding may delay adoption of incompatible products. Finally, technical standards also reduce switching costs and thereby lock-in to specific technologies. Switching costs created by training in specific computer software programs can also be limited by standardized formats and user interfaces before transition to new technological platforms.

However, the socially optimal level of standardization in health care will depend on consumer heterogeneity. The greater the heterogeneity among consumers and their needs for ICT, the more important it will be to have flexibility in the design of ICT to meet those needs. Since there is much greater heterogeneity in health care – across medical conditions and among patients with a given medical condition – than among producers and their customers in other parts of the economy, product differentiation is particularly desirable. In fact, standardization can have greater negative consequences if the standards do not accommodate this heterogeneity. A tradeoff therefore exists between seeking more standardization to allow for greater adoption and less standardization to allow for greater product differentiation.

A tradeoff also exists between ICT performance and interoperability (Katz and Shapiro 1994; Govindaraju et al 2004; Sang-Hoon and Sungjoon 2004). ICT manufacturers need to consider whether to introduce technologies with the necessary interfaces and specifications to ensure compatibility with existing technologies or introduce incompatible, yet superior, technologies to increase their market share. Their financial reward is defined as the total value added to market of the new technology (e.g. the improvement it offers over existing technologies and how widely it is adopted) times their share of the market (Shapiro and Varian 1999). However, from a societal perspective the reward of introducing a new technology is simply the value added to the market regardless of who controls that market share. Due to the complicated switching costs in health care, standards that ensure backwards compatibility, and hence quicker adoption of new technologies, are likely to result in the greatest societal value of a new technology. In addition, to avoid market dominance of any one vendor and hence inspire competition to improve the available technologies, the standards for interoperable ICT should be as non-proprietary as possible.

Given the many possible applications of ICT to chronic disease care it is critical to consider the type of ICT for which we should have standards. There are multiple ICT applications where compatibility is essential for an optimal use such as medical devices that capture patients´ biometric data, software that transmit such data, the operations of the EMR with multiple interactions with different software and databases across providers, and the different user interfaces that read and present such data. For instance, applications of medical informatics in diabetes care that aim to integrate blood sugar data with data on food consumption, medication and exercise for transmission to the EMR effectively require a standard for the patient's device, a standard for communicating to the software that analyzes this data and a standard for the software to communicate with EMR. There are multiple possible places for standardization and multiple interoperability issues. The type of information that needs to be recorded, manipulated and analyzed is also much more heterogeneous, which makes the standard setting particularly challenging.

The ideal ICT standard will vary across chronic diseases. The technology that will be optimal for diabetes care is not likely to be optimal for the treatment of heart disease and it is therefore not obvious what technical standard to work for given the possible ICT applications. Envision a standard EMR adopted in all hospitals without regard to the specific infrastructure, medical specialties and patient populations treated at each hospital. Such an EMR could do more harm than good in medical care. However, a common operating platform could establish the communication standard if it allows for disease-specific modifications to address diversity in ICT needs. For example, the ability to add new modules and to add new variables and data structures for those new modules is critical, because new medical tests and new ways of analyzing data will be developed. Flexible means of communicating across new modules will also be essential. A common operating platform expandable on a flexible basis to address ICT needs for specific diseases will ensure use of ICT across providers, and thereby provide network externalities. The practicalities of how much of the operating platform that should be universal and how much should be idiosyncratic is clearly an open question. Due to the heterogeneity and idiosyncrasies in health care and among chronic diseases, we need flexibility to ensure disease-specific technical modifications around the communication standard and therefore we cannot have full ICT compatibility. An open non-proprietary technical platform that allows others to write for it and develop specific ICT systems will go along way for addressing the need for product differentiation.

Many of the standards needed for interoperable health care ICT already exist in some form today, and many organizations have been involved in developing specific standards for health care (Hammond 2005). The Certification Commission for Health Information Technology (CCHIT) has worked on the key health information technology functionalities and requirements necessary for certification (Rosenfeld et al 2005). Private standard-setting organizations (SDOs) such as Health Level Seven/Institute of Medicine collaboration, Integrated Healthcare Enterprise, and ASTM International are working to facilitate development and integration of uniform standards. As work on standards for electronic health records has expanded over the last couple of years, the vendor community has also formed a trade alliance (the Electronic Health Record Vendor´s Association) to protect their propriety interests. Finally, the American National Standards Institute (ANSI), a private non-profit organization that administers and coordinates the U.S. voluntary standards activities, has set up the Healthcare Information Standards Board to coordinate efforts among SDOs working for standards in health care.

Despite all these initiatives there exists no overall plan for how standards should be defined and the overall principles that should guide their design to ensure an optimal societal use of ICT. Equally important, no one has identified all the standards needed to support interoperability of health care ICT. The initiative by Connecting for Health is promising in this regard (Halamka et al 2005). The organization proposes a minimum set of standards that aims to protect privacy, patient control and data security, while allowing timely access to data across information networks. These standards will facilitate interoperability of standard interfaces and transactions at local, regional and national levels and address secure transport of data, provide the essential components required for the infrastructure, including secure connectivity, reliable authentication, and formats for health data. By focusing on a minimum set of standards that provides for interoperability, the approach recognizes the heterogeneity in technology needs and applications that is crucial in health care ICT.

However, to reach agreement on specific standards, including the policy guiding data use and exchange, a formal standard setting process is needed. Most standard setting for new technologies in the U.S. today takes place through formal balloting processes defined by the ANSI (Hammond 2005). This process is governed by a set of rules and procedures for reaching consensus on technical decisions, including a requirement that the ballot is open to anyone to avoid dominance of any single group of stakeholders. While the formal process is often criticized for being slow, cumbersome, and political (David & Shurmer 1996), it has historically been absolutely critical to launching new technologies (Shapiro and Varian 1999). The process will need to involve the SDOs already engaged in standard setting as well as the vendor community to ensure a critical mass of technical expertise while providing a vendor-neutral solution. Medical input will also be needed, including all major patient advocacy groups for chronic diseases (e.g. the American Diabetes Association, the American Heart Association, and the American Cancer Society), to specify the right unique standard for the each disease and ensure interoperability with other health care ICT. Other key stakeholders include all major types of providers (e.g. represented by the American Academy of Family Physicians and the American Hospital Association), all major health insurers (e.g. represented by American Health Insurance Plans and Centers for Medicare and Medicaid Services). Involvement of all these stakeholders does predict a slow and cumbersome process, and thereby short-term static losses, however in the long-run it is likely to produce the most optimal solution.

To coordinate the process, a public-private or non-profit entity will be necessary (Halamka et al 2005; Hammond 2005). With a representation and consultation structure involving all stakeholders, the entity should identify, specify, and disseminate the policies and standards necessary for sharing electronic health information. It should also develop detailed technical specifications for implementation to ease adoption by providers. The policies will govern the rules on privacy, security, user authorization, and application of patient data, while the standards will enable data recording and data sharing in compliance with these specific policies. The policies and standards should be designed in a flexible way that enables adjustment to technological progress.

The role of the government should also be considered bigger than just setting standards. The importance of "influentials" for ensuring technology adoption has been debated in the business literature for quite some time (Chakravorti 2003; Berry & Keller 2003), but for health care ICT the role of the government is likely to be critical. By financing, endorsing and adopting technologies, the government can help achieving a critical mass of consumers for ICT, which subsequently leads to rapid uptake and widespread use (Rosenfeld et al 2005; Middleton 2005). Network externalities imply that for many forms of ICT there will be a long, slow, increase in their use until some critical mass is reached and after which growth explodes. The internet, which was initially developed and financed by the U.S. Department of Defense, is a good example of how the government facilitated a critical mass of consumers for use of ICT. The internet is also a good example of how for certain types of technologies a clear technical platform is needed in order to develop new forms of ICT. The interlinked markets and resulting mismatch in financial incentives for ICT adoption is a strong argument for government involvement. The fragmentation of the markets in health care, and the fragmentation within the markets (among providers and insurers), also argue for the government to play a leading role in setting standards to bridge these markets. However, the government, in lending support for particular standard, need to take into account all private interests. Due to their sheer size, ICT decisions by public insurers such as Medicare and Medicaid have consequences far beyond their beneficiaries and tax-payers. For instance, if Medicare decided to endorse one specific EMR to fit the Medicare population but not other patient groups, then this could be a huge obstacle for more widespread adoption of the EMR.

## VI: The Value of Waiting

The slow adoption of ICT in health care relative to other industries clearly implies societal losses in a static framework; potentially valuable adoption opportunities are missed. However, in a dynamic context with great uncertainty about the optimal health care ICT, the picture is less clear. As described, the future value of specific ICT systems is highly uncertain, not only due to rapid technological change but also the uncertainty relating to adoption decisions by other providers and insurers—and hence uncertainty about the network externality. Moreover, decisions to adopt ICT are irreversible, because not only are the costs sunk but a variety of lock-in effects occur. Once system-wide technology adoption has occurred in health care, it is hard, if not impossible, to turn back to previous systems of communication and information storage. Though the combination of uncertainty and irreversibility of ICT investment generally reduce the value of ICT investments, these two factors are likely to substantially affect the value of ICT in health care.

Recent advances in investment theory, referred to as the real option value theory of investment, have stressed the value of waiting to invest when there is uncertainty and investments are irreversible (Dixit and Pindyck 1994; Luerhman 1998). This theory, used to value capital investments in the corporate world, has recently been applied in the social sector as well, including ICT adoption in higher education (Oslington 2004). The theory makes the general point that if one invests now, when the future value of the investment is uncertain, the return on the investment may be either high or low depending on future market conditions, yet investing now destroys the option to invest at a later time point. However, if one waits until the uncertainty is resolved, the value of the investment will be known and the optimal decision—whether to invest or not and the specific type of investment—can be made. Consider a provider's decision to invest in a particular health care ICT without knowing whether a much better technology will come along and/or before he knows what specific type of ICT other providers will adopt. If the provider maintains his option to invest at a later time point, he can invest when other providers have made clear the type of ICT they consider acceptable. The option value theory directly conjoins with the theory of technology adoption when network externalities and the positive feedback are present. While network externalities in general may delay or completely prevent adoption of technologies, this effect can be compounded by the effect of uncertainty and irreversibility of investment.

Formally, the option value of an investment is defined as the difference between the present value of the investment if delayed and the present value of the investment now. This value increases with uncertainty (Dixit and Pindyck 1994). In particular, the greater the uncertainty about technological progress and future technologies available, market demands, and the regulatory requirements for technologies adopted, the more valuable the option to delay investments will be when these are irreversible.[1] To the extent that uncertainty is greater in health care, due to technological change in the medical information required and changing regulatory requirements, the value of waiting will be higher in health care.

The value of delaying investment also increases with the cost of adopting the wrong technology. Due to network externalities and positive feedback, the cost of adopting the wrong ICT is generally higher than other kinds of technology. In health care, the value of delaying investments in ICT is likely to be so much greater than in other sectors because the costs of adopting the wrong type of ICT will be so much higher.

What are the reasons that the penalty for the wrong ICT adoption is so much greater in health care? First, relative to other industries (such as banking), the consequences of technical errors in medical care are likely to be larger in magnitude,

[1] Of course there may be situations, where investment now is a prerequisite for investing later, such as IT infrastructure to even maintain current clients, but in general the value of waiting is positive.

more salient, more attention-getting, and engender stronger emotions. Most importantly, some errors in medical care are completely irreversible, such as permanent disability and death. While certain consequences of technical errors are private to the providers (such as salience and attention-getting), others are genuinely societal, in particular premature death. Therefore, if technical problems exist in the operations of ICT, for reasons of poor interoperability or data storage, the consequences for both the early adopters and society at large can be severe. Second, the much more complicated and larger switching costs in health care, due to the large number of actors and the coordination problems among them, makes the financial losses resulting form the wrong ICT adoption so much greater in health care. The mere fragmentation of the health care markets and fragmentation within the markets may imply substantial financial losses to any individual provider and insurer if their particular ICT system is not compatible with the future standards and requirements for health care ICT. Third, the federal regulation protecting the confidentiality of health information introduced by Health Insurance Portability and Accountability Act of 2003 implies that being stranded with an incompatible technology or losing information due to system failure and breakdown is simply not an option (U.S. Department of Health and Human Services 2003). Many states have introduced legislation that set even higher standards for how patient data should be protected and the extent to which it can be shared across providers (Gottlieb et al 2005). The effect of these federal and state regulations is an increase in the cost of adopting the wrong technology. As noted above, if providers adopt ICT too early, they are likely to be locked to that technology. In medical practice this kind of lock-in is simply not a clinical or legal option as medical records must be accessible at all times.

The uncertainty in returns of ICT investments and the irreversibility of these investments may imply that there are real advantages to going slowly and waiting for the right technology to come along before system-level adoption takes place. Take the example of the EMR for instance, currently adopted by approximately 5% of all U.S. hospitals for computerized physician order entry (Jha et al 2006). The fact that no widespread adoption of the EMR took place ten years ago when the first versions were introduced may actually, from a societal perspective, have been the right decision. The technical standards available at the time did not provide for the kind of interoperability needed today for an optimal use of the technology. If half of all U.S. hospitals had adopted the EMR back then they may have been locked into a technology that could not be used for all the clinical applications needed today. Given the large collective switching costs providers need to be careful about the technologies they lock into and going slowly may in fact not only be a good idea but also the optimal approach in health care.

The risk of lock-in is also important for understanding the likely adoption path of health care ICT. The greater the cost of adopting the wrong kind of ICT, the more tendencies the system will exhibit towards incrementalism. The system also faces a specific challenge in how to overcome collective switching costs and create a network of users. To what extent does one provider in a given integrated care network benefit from the adoption of the same ICT by another provider in another network? To what extent does one payer benefit from another payer adopting a particular form of ICT? Among the two basic paths for technology adoption – the evolution path of incremental adoption versus the revolution path of rapid adoption of superior, yet incompatible, technology – the evolution path may be the only realistic option in health care given uncertainty in the value of existing technologies and the irreversibility of investment. Finally, if one accepts that U.S. health care is characterized by a lagging effect in which its history influences its current structure – by hysteresis – then there will be limits to how far and how fast we can go in adopting ICT. This may also imply that the best technology solution will never be adopted. In summary, there does not seem to be something like an ideal time for ICT adoption, but rather due to the inherent uncertainties in the value of new technology, irreversibility of the investments, lack of standards, and the many interlinked markets, slow incremental adoption seems to be not only the optimal but also the realistic way forward.

## VII. Conclusions

ICT in chronic care potentially brings large societal benefits through improved patient outcomes, and lower direct and indirect resource use. Evident from a great deal of experimental use, ICT facilitates such benefits through rapid and frequent communication and collection of patient data allowing better monitoring and provider intervention. Easy assembly of information from different sources through the EMR, such as laboratory tests, self-monitored and hospital data also provides a better overview of patient status. More generally, wider and more rapid dissemination of information and information analysis, presentation and interpretation allow many more health care professionals to provide quick input to the chronic care of the patient. Finally, ICT may make disease management less time consuming. Patient self-care may be easier and more convenient, while the ability to communicate quickly and share all relevant information in easy to digest form eases the burden on coordinating care.

Unlike a standard perfectly competitive market where every firm adopt the amount and type of technology needed to operate in the most efficient way, the ICT market has a number of unique features which may delay or completely prevent the adoption of beneficial technologies. The main barriers to ICT adoption include low product differentiation, high switching costs in replacing technologies, and lack of technical compatibility of all the different components of ICT. In contrast to most markets in the economy where suppliers have incentives to adopt technologies that improve service and/or make production more efficient, health care providers and payers do not have such incentives due to bundling of health care services and insurance, the traditional basis of payment, selection issues and most importantly, the myriad of interlinked markets. The people who are really interested in ICT adoption are the patients, yet they lack direct means of influence. Employers will be motivated if their employees care sufficiently to affect employment decisions or if productivity is affected. Government will be motivated if there is sufficient voter interest. Both government and employers need to influence insurers´ payment policies; however insurers will only be interested if the technologies offer sufficient cost-effectiveness potential.

The interlinked market forces in health care combined with great consumer heterogeneity significantly intensify the barriers to ICT adoption. The many actors on the consumer side compared to the usual ICT market, and the many more actors on both the producer and consumer side compared to the standard market makes the question of who will benefit from ICT adoption and who will pay for the adoption significantly harder to answer than in other sectors of the economy. Switching costs exist for all actors in the health care market and those switching costs are exacerbated not only by the many different types of consumers, but also their highly varying needs.

The value of any ICT is fundamentally linked to the ability to connect with other users and share that information. When manufacturers develop new forms of ICT they need to consider whether the products should be compatible with existing products and thereby accept old performance standards or bring about completely new, yet incompatible, technologies offering vastly superior performance. Given the myriad of consumers in health care and the resulting significant and complicated switching costs, major and rapid changes in the type of ICT applied in heath care cannot be expected. Even if all initial barriers to ICT adoption should be addressed, slow incremental change in health care ICT is likely to be the future norm rather than exception. This pace of ICT adoption basically reflects a trade-off that exists when innovative technologies clashes with the network externalities and their associated switching costs.

Standards that ensure interoperability will be critical for adoption of health care ICT. By enhancing interoperability, common technical standards also generate greater value to users by expanding the network, and hence increase the network externality. In addition, they reduce the likelihood of being stranded with an incompatible technology, and they reduce the switching costs and hence risk of lock-in to old technologies.

However, the socially optimal level of standardization in health care will depend on consumer heterogeneity, which implies a tradeoff between seeking more standardization to allow for greater adoption and less standardization to allow for greater product differentiation. A tradeoff also exists between ICT performance and interoperability. Given the complicated switching costs in health care, standards that ensure backwards compatibility are likely to results in the greatest societal value of ICT, even if implies sacrificing some productivity gains. Due to the heterogeneity and idiosyncrasies in health care, the ideal ICT standard will vary across chronic diseases. An open non-proprietary technical platform that allows others to write for it and develop disease-specific ICT systems will be crucial for product differentiation.

To reach agreement on specific standards, a formal, yet open, standard setting process is needed. This approach will need to involve the SDOs already engaged in standard setting and the vendor community to provide the technical expertise while ensuring a vendor-neutral solution. Medical input will also be needed, including all major patient advocacy groups, the different kinds of health care providers and health insurers to specify the right unique standard for the each disease and ensure interoperability with other health care ICT. The resulting policies and standards should be designed to enable adjustment with future development and technologies. The government should play a leading role in the standard setting process given its ability to bridge the many fragmented, yet interlinked, markets in health care.

Rapid change in ICTs available, the uncertainty of the network externalities associated with any specific ICT, and the irreversible nature of the ICT investment in general implies a reduction in the present value of ICT. The uncertainty about the optimal form and type of health care ICT and the legal framework regulating its use indicates that the value of waiting to invest in ICT is likely to be greater in health care than in other sectors. However, the value of waiting is also likely to be greater in health care because the costs of adopting the wrong type of ICT are so much higher. In particular, the risks of technical errors are much more prominent in health care, and in some instances the consequences are irreversible, placing great demands on the reliability of the system. The risk and consequences of lock-in to a suboptimal technology are also greater in health care. The many layers of ICT adoption in health care and the resulting significant switching costs implies that once system-wide adoption has occurred, it will be hard if not impossible to turn back to previous systems of communication and data storage. However, federal and state legislation implies that being stranded with an incompatible technology or losing information due to system failure is simply not an option.

In addition to the special features of ICT and the health care market, and the critical importance of standards, many other factors significantly influence adoption, including reimbursement. From our analysis of the health care system, we now know who the players are who have an interest in ICT adoption; patients, employers and insurers, from most to least motivated. In order to get providers to actually adopt, we believe that payment in some form is crucial. The specific form of payment is also likely to affect the type of ICT adopted and the extent to which an optimal use of ICT will take place (Christensen & Remler 2007). A separate motivation for adopting ICT in chronic disease care is clearly the potential to improve quality and thereby patient outcomes. However all the barriers relating to interoperability, high switching costs, and irreversibility of investment still need to be overcome even when the adoption is not financially motivated.

ICT is here to stay and certainly will be important in the future of health care: it's potential for improving health and decreasing both direct and indirect costs seems impressive. While much of that potential is clearly not being met at this time, the slow adoption may not be as sub-optimal as one may think, because the costs of adopting the wrong ICT are so much higher in health care. Many of the barriers to adoption can be overcome, and overcome in a way that ensures a better final outcome, by an open and reflective standards setting process that includes all relevant stakeholders. While such a process will be slow and cumbersome, it will avoid lock-in to sub-optimal ICTs and help ensure sensitivity to the wide variety of private and societal interests.

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**References**

Aaron HJ. Economic Issues in Health care in Serious and Unstable Condition: Financing America's Health care”. Chapter 2, p. 8-37. 1991. Washington DC: Brookings.

Andrews, M. Money & Medicine: Access Fees for Doctors? Some Test the Waters. *New York Times*, November 16, 2003.

Arrow, K. Uncertainty and the Welfare Economics of Medical Care. *American Economic Review* 1963; 53(5): 941-973.

Artinian, N.T., O.G. Washington, and T.N. Templin. Effects of Home Telemonitoring and Community-Based Monitoring on Blood Pressure Control in Urban African Americans: A Pilot Study. *Heart and Lung* 2001; 30: 191-199.

Asmar, R, and A. Zanchetti. Guidelines for the Use of Self-Blood Pressure Monitoring: A Summary Report of the First International Consensus Conference. *Journal of Hypertension* 2000; 18: 493-508.

Belluck P. Doctors' New Practices Offer Deluxe Service for Deluxe Fee. *New York Times* National Desk, Late Edition, Section A, Page 1, Column 5, January 15, 2002..

Berry J, Keller E. The Influentials: One American in Ten Tells the Other Nine How to Vote, Where to Eat, and What to Buy. 2003. Free Press.

Bondmass, M, Bolger N, Castro G, Avitall B. The Effect of Physiologic Home Monitoring and Telemanagement on Chronic Heart Failure Outcomes. *The Internet Journal of Asthma, Allergy and Immunology* 1999; 3(2): XX.

Brailer DJ[A]. Economic Perspective on Health Information Technology. *Business Economics* July 2005; 6-11.

Brailer DJ[B]. Interoperability: The Key To The Future Health Care System. *Health Affairs* 2005; 24, Supplement 1: W5-19 to W5-21.

Burton LC, Anderson GF, Kues IW. Using Electronic Health Records to Help Coordinate Care. *Milbank Quarterly* 2004; 82(2): 457-481.

Car J, Sheikh A. Telephone Consultations. *British Medical Journal* 2003; 326: 966-969.

Cavallo L, Rossi S. Scale and Scope Economies in the European Banking Systems. *Journal of Multinational Financial Management* 2001; 11 (4-5): 515-31

Chakravorti B. The Slow Pace of Fast Change: Brining Innovations to Market in a Connected World. Harvard Business School Press. 2003.

Chetney R. Home Care That Dosen´t Miss A Beat. *Home Healthcare Nurse* 2003; 21(10): 681-686.

Christensen MC, Remler DK. Information and Communication Technology in Chronic Disease Care: What Are the Implications for Payment? *Medical Care Research and Review* 2007; 64 (2): 123-147.

Congleton R. The Median Voter Model. In C. K. Rowley (Ed.); F. Schneider (Ed.) The Encyclopedia of Public Choice. Kluwer Academic Press, 2003.

Cutler DM, McClellan M. Is Technology Change in Medicine Worth it? *Health Affairs* 2001; 20(5): 11-29.

Cutler DM, Feldman NE, Horwitz JR. U.S. Adoption Of Computerized Physician Order Entry Systems. *Health Affairs* 2005; 24(6): 1654-1663.

Dranove D, White WD. Agency and the Organization of Health Care Delivery. *Inquiry* 1987; 24:  405-415.

Danzon PM, Furukawa MF. Health care: Competition and Productivity in The Economic Payoff from the Internet Revolution, Robert E. Litan and Alice M. Rivlin, eds. Washington DC: Brookings. 2001.

David PA, Shurmer M. Formal Standards-Setting for Global Telecommunications and Information Services. *Telecommunication Policy* 1996; 20(10): 789-815.

Diabetes Forecast. Pairing your Meter with Software. January 2006, p. RG42.

Dixit AK, Pindyck R. Investment under Uncertainty. Princeton: Princeton University Press. 1994.

Evans DC, Nichol PW, Perlin JB. Effect of the Implementation of an Enterprise-wide Electronic Health Record on Productivity in the Veterans Health Administration. *Health Economics, Policy and Law*  2006;1: 163-169.

Farrell J, Saloner G. Standardization, Compatibility, and Innovation. *RAND Journal of Economics* 1985; 16: 70-83.

Gelijns AC, Zivin JA, Nelson RR. Uncertainty and Technological Change in Medicine. *Journal of Health Politics, Policy and Law* 2001; 26(5): 913-924.

Glied S. Chronic Condition: Why Health Care Reform Fails. Cambridge, Mass. Harvard University Press. 1997.

Govindaraju M, Slominski A, Chiu K, Liu P, van Engelen R, Lewis MJ. Toward Characterizing the Performance of SOAP Toolkits. In Proceedings of the 5th IEEE/ACM International Workshop on Grid Computing, Pittsburg, Short paper: 365-372. 2004.

Goodman C. Savings in Electronic Medical Record Systems? Do It For The Quality. *Health Affairs* 2005; 24(5): 1124-1126.

Gottlieb LK, Stone EM, Stone D, Dunbrack LA, Calladine J. Regulatory and Policy Barriers to Effective Clinical Data Exchange: Lessons Learned From MedsInfo-ED. *Health Affairs* 2005; 24(5): 1197-1203.

Goldsmith, J. The Internet and managed care: A new wave of innovation. *Health Affairs* 2000; 19(6): 42-56.

Grigsby J, Sanders JH. Telemedicine: Where It Is and Where It´s Going. *Annals of Internal Medicine* 1998; 129: p.123-127.

Halamka J, Overhage M, Ricciardi L, Rishel W, Shirky C, Diamond C. Exchanging Health Information: Local Distribution, National Coordination. *Health Affairs* 2005; 24 (5): 1170-1179.

Hall BH. Adoption of New Technology. *NBER Working Paper Series*. Working paper 9730. 2003.

Hammond EW. The Making and Adoption of Health Data Standards. *Health Affairs* 2005; 24 (5): 1205-1213.

Hillestad R, Bigelow J, Bower A, Girosi F, Meili R, Scoville R, Taylor R. Can Electronic Medical Record Systems Transform Health Care? Potential Health Benefits, Savings and Costs. *Health Affairs* 2005; 24(5): 1103-1117.

Hosken D, Simpson JD. Have Supermarket Mergers Raised Prices? An Event Study Analysis. *International Journal of the Economics of Business* 2001; 8(3): 329-42.

Institute of Medicine, Committee on Evaluating Clinical Applications of Telemedicine. Telemedicine: A Guide to Assessing Telecommunications in Health care. Washington, D.C.: National Academy Press. Marilyn J. Field, Editor. 1996.

Institute of Medicine. Key Capabilities of an Electronic Health Record System: Letter Report. 2003a. Available at http://www.nap.edu. Accessed January 8, 2006.

Institute of Medicine. Priority Areas for National Action: Transforming Healthcare Quality". In Committee on Identifying Priority Areas for Quality Improvement, edited by K. 2003b. XX

Jerant A, Rahman A, Thomas NS. Reducing the Cost of Frequent Hospital Admissions for Congestive Heart Failure: A Randomized Trial of a Home Telecare Intervention. *Medical Care* 2001; 39(11):1234-1245.

Jha AK, Ferris TG, Donelan K, DesRoches C, Shield A, Rosenbaum S, Blumenthal D. How Common Are Electronic Health Records in the United States? A Summary of the Evidence. *Health Affairs* 2006, Web Exclusive, p: W496 – W507.

Kaiser Permanente. Kaiser Permanente Annual Report. Quality You Can Trust. 2002. Available on-line at: http://xnet.kp.org/annualreport/2002/kp_report_2001_2.pdf . Assessed January 2006.

Kassirer JP. Patients, physicians, and the Internet. *Health Affairs* 2000; 19(6): 115-23.

Katz M, Shapiro C. Network Externalities, Competition, and Compatibility. *American Economic Review* 1985; 75(3): 424-440.

Katz ML, Shapiro C. Systems Competition and Network Effects. *Journal of Economic Perspectives* 1994; 8(2): 93-116.

Kleinke JD. Vaporware.com: The Failed Promise of the Health Care Internet. *Health Affairs* 2000; 19(6): 57-69.

Kuszler PC. Telemedicine and Integrated Health care Delivery: Compounding Malpractice Liability. *American Journal of Law & Medicine* 1999; 25: 297-326.

Lehoux P, Battista RN, Lance J-M. Telehealth: Passing Fad or Lasting Benefits? *Canadian Journal of Public Health* 2000; 91(4): 277-280.

Lloyd-Jones DM, Larson MG, Leip EP, Beiser A, D´Agostino RB, Kannel WB, Murabito JM, Vasan RS, Benjamin EJ, Levy D. Lifetime risk for developing congestive heart failure – the Framingham heart study. *Circulation* 2002; 106(24): 3068-3072.

Luehrman TA. Strategy As A Portfolio of Real Options. *Harvard Business Review*, September-October 1998: 89-99.

Middleton B. Achieving U.S. Health Information Technology Adoption: The Need For A Third Hand. *Health Affairs* 2005; 24(5): 1269-1272.

Miller RH, West C, Brown TM, Sim I, Ganchoff C. The Value Of Electronic Health Records in Solo Or Small Group Practices. *Health Affairs* 2005; 24 (5): 1127-1137.

National Library of Medicine. Medical Subject Headings (MeSH). 2001. Available at: http://www.nlm.nih.gov/cgi/mesh/2K/MB_cgi?term=Medical+Informatics&field=entry#TreeL01.700. Accessed March 2, 2007.

Newhouse JP. Patients At Risk: Health Reform And Risk Adjustment. *Health Affairs* 1994; Spring (I): 132-145.

Newshour with Jim Lehrer. John Castellani, president of Business Roundtable in Wal-Mart, Union Leaders Collaborate on Health Care. February 8, 2007. Transcript available at: http://www.pbs.org/newshour/bb/health/jan-june07/healthcare_02-08.html Accessed March 5, 2007.

Ortiz E, Clancy CM. Use of Information Technology to Improve the Quality of Health care in the United States. *Health Services Research* 2003; 38(2): 11-22.

Oslington P. The Impact of Uncertainty and Irreversibility on Investments in Online Training. *Distance Education* 2004; 25(2): 233-242.

Pauly M. Overinsurance and Public Provision of Insurance: The of Moral Hazard and Adverse Selection. *Quarterly Journal of Economics* 1974; 88: 44-62.

Pedersen MK, Fomin VV. The Economics of Standards and Standardization in Information and Communication Technologies. Open Standards and Their Early Adoption. Open Standards Research Report. 2005. Available on-line at: **http://ir.lib.cbs.dk/download/ISBN/x656517335.pdf**. Accessed March 15, 2007.

Perlin JB, Collins DA, Kaplowitz LG. Telemedicine. *Hospital Physician* 1999; 36: 26-34.

Puskin DS. Telemedince: Follow the Money. Online Journal of Issues in Nursing. 2001. Available at: **http://nursingworld.org/ojin/topic16/tpc16_1.htm.** Accessed March 2, 2007.

Rice T, Labelle R. Do Physicians Induce Demand for Medical Services? *Journal of Health Politics, Policy and Law* 1989; 14: 587-600.

Roglieri JL, Futterman R, McDonough KL, Malya G, Karwath KR, Bowman D, Skelly J, Warburton SW. Disease Management Interventions to Improve Outcomes in Congestive Heart Failure. *Journal of American Managed Care* 1997; 3(12): 1831-1839.

Rohlfs J. A Theory of Interdependent Demand for a Communication Service. *Bell Journal of Economics* 1974; 5: 141-156.

Rosenfeld S, Bernasek C, Mendelson D. Medicare´s Next Voyage: Encouraging Physicians to Adopt Health Information Technology. *Health Affairs* 2005; 24(5): 1138-1158.

Sawin CT, Walder DJ, Bross DS, Pogach LM. Diabetes Process and Outcome Measures in the Department of Veterans Affairs. *Diabetes care* 2004; 27, Suppl 2; B90. XX

Sang-Hoon K, Sungjoon N. Across the Threshold: Role of Performance and Compatibility in Innovative New Products´ Market Penetration. *Industrial Marketing Management* 2004; 33: 689-699.

Shapiro C, Varian HR. Information Rules. Boston, Mass. Harvard Business School Press. 1999.

Shea S, Starren J, Weinstock R, Knudson P, Teresi J, Holmes D, Palmas W, Field L, Goland R, Tuck C, Hripcsak G, Capps L. Columbia University's Informatics and

Telemedicine (IDEATel) Project: Rationale and Design. *Journal of the American Medical Informatics Association* 2002; 9(1): 49-62.

Shortliffe EH. Strategic Action in Health Information Technology: Why The Obvious Has Taken So Long. *Health Affairs* 2005; 24(5): 1222-1231.

Shy O. The Economics of Network Industries. Cambridge: University of Cambridge Press. 2001.

Sparer MS. Medicaid and the limits of state health reform”. Philadelphia : Temple University Press. 1996.

Spielberg AR. On Call and Online. *Journal of the American Medical Association* 1998; 280(15): 1353-1359.

Spielberg AR. Online Without a Net: Physician-Patient Communication by Electronic Mail. *American Journal of Law & Medicine* 1999; 25: 267-295.

Stanberry B. Telemedicine: Barriers and Opportunities in the 21st Century. *Journal of Internal Medicine* 2000; 247: 615-628.

Starren J, Hripscak G, Sengupta S, Abbruscato CR, Knudson PE, Weinstock R, Shea S. Columbia University’s Informatics and Telemedicine (IDEATel) Project: Technical Implementation. *Journal of the American Medical Informatics* Association 2000; 9(1): 25-36.

Taylor R, Manzo J, Sinnett M. Quantifying value for physician order-entry systems: a balance of cost and quality. *Healthcare Financial Management* 2002; 56(7): 44-48.

Wang SJ, Middleton B, Prosser LA, Bardon CG, Spurr CD, Carchidi PJ, Kittler AF, Goldszer RC, Fairchild DG, Sussman AJ, Kuperman GJ, Bates DW. A Cost-Benefit Analysis of Electronic Medical Records in Primary Care. *American Journal of Medicine* 2003; 114(5): 397-403.

Walker J, Pan E, Johnston D, Adler-Milstein J, Bates DW, Middleton B. The Value of Health Care Information Exchange and Interoperability. *Health Affairs* 2005; 24, Supplement 1: W5-10 to W5-18.

Wallace DJ.Gadget Knows Grandma Inside Out. *New York Times*, October 23, 2003, http://www.nytimes.com/2003/10/23/technology/circuits/23elde.html, Accessed March 2, 2007.

Weisbrod BA. The Health Care Quadrilemma: An Essay on Technological Change, Insurance, and Cost Containment. *Journal of Economic Literature* 1991; 29 (2): 523-552.

White House, Office of the Press Secretary. Fact Sheet: Improving Care and Saving Lives Through Health IT. 2005. Available on-line at: **http://www.whitehouse.gov/news/releases/2005/01/20050127-2.html.** Accessed March 2, 2007.

Whitten PS, Mair FS, Haycox A, May CR, Williams TL, Hellmich S. Systematic review of cost effectiveness studies of telemedicine interventions. *British Medical Journal* 2002; 324: 1434-1437.

U.S. Department of Health and Human Services. Protecting the Privacy of Patient´s Health Information. 2003. Available at: **http://www.hhs.gov/news/facts/privacy.html**. Accessed March 8, 2007.

U.S. General Accounting Office. Private Health Insurance: Small Employers Continue to Face Challenges in Providing Coverage. 2001. Available at: http://www.gao.gov/new.items/d028.pdf. Accessed March 2, 2007.

Zuvekas SH. Trends In Mental Health Services Use And Spending, 1987-1996; While access to mental health services has greatly increased, high out-of-pocket costs still deter many from seeking treatment. *Health Affairs* 2001; 20(2): 214-225.