Information Technology and Life Expectancy: A Country-Level Analysis

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INFORMATION TECHNOLOGY AND LIFE EXPECTANCY: A COUNTRY-LEVEL ANALYSIS

Completed Research Paper

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Abstract

Do countries with higher IT spending have higher life expectancy? Recent policy debate on healthcare in the United States has focused on the role of IT in reducing costs and improving healthcare access and quality. An implicit assumption in this debate has been that greater infusion of IT into healthcare will lead to better health outcomes. We investigate the validity of this assumption by examining the extent to which higher IT expenditures at the country level are associated with higher life expectancy, a key measure of healthcare outcomes. Drawing on the information systems and supply chain management literature, we theorize three mechanisms to explain why IT may be associated with healthcare outcomes at the country level: information integration, workflow coordination, and collaborative planning. We then conduct an empirical analysis relating IT investments with life expectancy and find that higher IT investments at the country level are positively associated with higher life expectancy. We discuss implications of the findings for further research and policy.

Keywords: Information technology, information technology investments, health care, life expectancy, longevity, country-level analysis, business value of IT


**INFORMATION TECHNOLOGY AND LIFE EXPECTANCY: A COUNTRY-LEVEL ANALYSIS**

**Introduction**

Healthcare, a key indicator of human development, has emerged as an important public policy issue across the globe. While life expectancy has increased globally over last several decades, significant cross-country differences in these indicators remain a cause for concern (Becker, Philipson and Soares 2005; Bourguignon and Morrision 2002). In many countries including several developed economies such as the US, the healthcare system is suffering from rapidly escalating costs, declining quality of care, and preventable medical errors (Bohmer and Knoop 2006; Reid 2009). The national health spending of the US in 2006 at $ 2.1 trillion (approximately 16% of GDP) is increasing at a projected growth rate of over 6 % to reach $4.1 trillion USD by 2016 (Poisal et al. 2006). Other countries are also experiencing rising healthcare costs (Anderson and Hussey 2001; Anderson et al. 2006). Because of the important role of information technology (IT) to potentially improve healthcare, IT figures prominently in debates surrounding healthcare reform.

IT can have a positive impact on health at the country level. Information and communication technologies, together with advances in medical science, drug design, disease management, and biomedical engineering, offer significant opportunities to improve health outcomes through initiatives such as streamlined business processes, and cost effective and improved diagnosis and treatment of patients. These intermediate outcomes, in turn, are likely to result in a healthcare system with high quality, low cost and improved efficiency (Bates et al. 2001; Nenonen and Nylander 2002; Shortliffe 1998).

However, greater use of IT in healthcare also raises some concerns. Some worry that IT-enabled “high-tech” automation without adequate attention to human aspects of care that involve “high-touch” may adversely affect quality of care. IT is also likely to aggravate inequalities caused by the digital divide: those who have IT access would be served better compared to those who do not have access to IT, while it is the latter who currently suffer most due to poor healthcare access. There is also a concern that an overemphasis and over-reliance on technology alone may deflect attention from more fundamental policy changes and incentive alignments that will likely be more efficient and effective in the long run.

Furthermore, from a policy perspective, it is not clear whether spending more money on IT in healthcare will be beneficial because very few studies have demonstrated the link between IT spending and improved health outcomes at the country level. While there is doubtless a momentum to promote adoption of IT in healthcare based on projections in early work that advocate infusion of IT based on its forecasted promise (Hillestead et al. 2005), more recent studies and articles have voiced concern about the potentially negative consequences of some of initiatives that focus on electronic medical records adoption and evidence-based care (see Groopman and Hartzband 2009; Lohr 2009). Overall then, the extent to which IT has an impact on health outcomes is an open empirical question and if pursued, can significantly inform public policies in this arena.

This study examines the extent to which IT investments at the country level are associated with improved health outcomes. We identify three mechanisms through which IT may affect the health outcomes. We collected data on IT investments and healthcare outcomes from several sources to evaluate the effect of IT on life expectancy. We find that countries with higher IT investments have higher life expectancy, while controlling for other relevant factors.

This study makes important contributions. We conceptualize the service delivery chain in the healthcare sector involving flows of information, drugs, and diagnoses through stakeholders such as doctors, patients, hospitals, governments and payers. We draw on the supply and service management literature to propose three mechanisms to understand the effect of IT on healthcare. We contribute to the value of IT literature
and extend that literature by focusing on life expectancy, an important metric of “well-being” that has received little attention so far (For a review of this literature, see Barua and Mukhopadhyay 2000; Brynjolfsson 1993; Brynjolfsson and Yang 1996; Dedrick, Gurbaxani and Kraemer 2003; Kauffman and Weill 1989; Lucas 1993). Unlike prior studies that focus mainly on tangible economic measures at the country level to assess the value created by IT, we assess the social value enabled by IT by examining life expectancy which is perhaps even more important from an individual and societal perspective (see Anand and Ravallion 1993).

Theoretical Framework

This study complements and extends several prior studies that investigate returns on IT at the country level, that have largely focused on the contributions of IT to economy level growth and productivity (Dewan and Kraemer 1998). Although early studies did not find the evidence of a significant relationship between IT and economic growth (Jorgenson and Stiroh 1999; Roach and Morgan Stanley Co. 1987); recent studies provide evidence that IT investments are associated with higher economic growth (Dewan 2000; Dewan and Kraemer 1998; Kraemer and Dedrick 1994). The country level studies by Dewan and Kraemer (1998) and Pohjola (2000) suggest that IT has differential impacts in developed and underdeveloped nations. These differences are attributed to variations in levels of IT investment relative to the GDP of the country, and the availability of complementary assets such as necessary infrastructure and knowledge base for the effective use of IT. Kauffman and Kumar (2008) also suggest that ICT readiness has a positive association with trade flows and R&D, but the impact depends on the country’s development.

We extend the prior studies by assessing the influence of IT investment on life expectancy. Following prior work in supply chain management and information systems literature (Cachon and Fisher 2000; Johnson and Whang 2002; Lin and Mithas 2008), we posit that information technology influences healthcare outcomes through three mechanisms: information integration, workflow coordination and collaborative planning.

Information Integration

Information integration refers to the merging or consolidation of information from disparate sources with differing conceptual, contextual and typographical representations. The consolidation and sharing of data from unstructured or semi-structured resources enables better communication and coordination in the value chain of a product or service (Lee and Whang 2003). Further, information integration also supports the sharing of data and processes between or within organizations through a virtually implemented structure; and helps to replicate integrated and synchronous processes (Lee, Farhoomand and Ho 2004; Vlisky and Smith 1994). The notion of information integration relates to the idea of the “wisdom of crowds” -- some consider such wisdom more reliable than expert judgment when the groups aggregate private judgments of group members who have diversity of opinion, exercise independent thinking, and use their decentralized (i.e., specialized and local) knowledge (Surowiecki 2004).

Information integration affects healthcare and health services in three ways. First, information integration helps in inter- and intra-hospital management and coordination processes through both internal and external integration (Raghupathi and Tan 2002). Second, information integration facilitates higher quality communication and coordination between different levels of care in healthcare services (e.g., primary, secondary and tertiary care, or between a hospital and a physician practice). Third, information integration enables the availability of accurate and right information at the time of need, along with better tools and applications for their archival, access and use anywhere, anytime and by anyone. This information availability is vital for efficient and quality healthcare delivery (Hersh 2004). Moreover, the availability of drug information and formularies for diagnosed diseases enable doctors to prescribe the correct drugs and most appropriate therapies needed for recovery; thereby increasing the quality of the care.

Information technology tools, applications and services influence and enable better information integration processes. The Internet-enabled IT systems provide the diagnostic, clinical and drug related information to doctors and health professionals at the time of need, thereby reducing the time lag in providing care. IT allows doctors and hospitals to have immediate access to data and information to make informed decisions.
in real-time. Such improvements in decision-making processes that involve patients or relevant diagnostic methods improves quality of care (Haux, Winter and Brigl 2003). Enterprise resource management systems help to improve the administrative efficiency of hospitals. Electronic medical record (EMR) systems have allowed hospitals to archive, exchange and unify fragmented data and applications, develop repositories of patient information, and provide support for evidence-based decision making in clinical care (Elson, Faughnan and Connelly 1997).

Likewise, inter-hospital multimedia communication systems and hospital-hospital telecommunication systems have enabled the smooth and seamless integration of hospitals in consultation, diagnosis and providing care (Lin 1999). Communication systems, such as telemedicine systems have enabled remote delivery of healthcare consulting services, overcoming the limitations of the physical infrastructure (Miscione 2007; Wootton 1997). For example, the telemedicine systems employed by Apollo hospital in India brings the primary and secondary levels of care into one platform (Sharma 2000) in an attempt to reduce the geographical constraints in healthcare service. In many cases, a primary care doctor needing an immediate intervention is able to call, e-mail, chat or even video-conference with a specialist on call in the secondary care or at the specialist hospitals (Branger 1992; Miscione 2007). He or she does not have to wait for the physical availability of the patient or for face-to-face communication to achieve this. Further, the data exchange between these levels of care or with the providers helps to provide effective diagnosis for critical cases, efficient specialist care for urgent cases, collaborative diagnosis of complex pathologies, and supports consultation among specialists and the primary care physicians. These information exchanges can improve the quality of care, thereby alleviating mortality due to a lack of timely intervention.

**Workflow Coordination**

Workflow coordination refers to the automated functioning or efficient performance of a sequence of operations. These operations might be the work of a person, a group of people, or the entire organization. Workflow coordination may be seen as any abstraction, aggregation or synchronization of real work and encompasses several activities, such as internal processes, job scheduling, procurement, order fulfillment, engineering change, design optimization, and financial exchanges; generally involving the detailed day-to-day operations of an organization (Fischer and Fischer 2003; Grover and Markus 2008). Organizations are increasingly adopting streamlined and automated approaches to coordinate their work processes with that of their supply chain partners, vendors and customers (Johnson and Whang 2002; Lee and Whang 2003).

In the context of healthcare services, workflow coordination supports the streamlining and rationalization of key processes in the care delivery value chain. Workflow coordination is particularly crucial for managing the workflow related with the exchange, access and sharing of the patient information (Malamateniou, Vassilacopoulos and Tsanakas 1998; Marina et al. 2005). It is also necessary for smooth functioning of administrative (e.g., payroll, business functions or order processing systems) and clinical functions (e.g., ambulance information management systems for a city (Derekenaris et al. 2001), ICU management system (Langenberg 1996), and emergency care (Poulymenopoulou, Malamateniou and Vassilacopoulos 2003)).

Workflow coordination affects healthcare delivery and practice by reducing cycle time in administrative and care delivery processes. It creates efficiencies by reducing the time taken for drugs or healthcare products to reach the market. Time is often of the essence to eradicate new diseases, or control the prevalence of repetitive diseases. For example, the production and distribution of anti-HIV vaccine or polio vaccine within a short time is necessary to reach vast populations scattered across large and often remote geographical areas (Hamid and Keith 2000).

IT is a key enabler of efficient and effective workflow coordination through the capabilities embedded in collaboration tools, resource management applications, and process integration tools. IT-enabled information organization and management helps in capture and recording, retrieval, and use of information; and, in turn, enhances the efficiency of the processes (Brown 1994; Hamilton 1999; Huber 1990). The efficient and improved processes aid in aligning and integrating inter- and intra- organizational functions, practices and systems. Beyond these improvements, IT enables basic functions such as scheduling, time management, ordering process, and other coordination mechanisms through patient scheduling systems,
patient information data exchanges, and operating-room coordination systems, providing the foundation for potential improvements in workflow coordination.

**Collaborative Planning**

Collaboration is a process where two or more people or organizations work together toward common goals. Collaboration in general and collaborative planning in particular is of considerable value in organizational settings (Lee and Whang 2003). Teams that work collaboratively can obtain greater resources, recognition and reward when facing competition for finite resources. Collaborative planning helps teams and organizations to plan projects and activities together with their peer base. The members of the team or organization participate, contribute, assign tasks and track the progress through collaborative planning, and jointly design and execute plans for product introduction, forecasting, and replenishment (Sahin and Robinson 2002; Vlosky and Smith 1994). Collaborative planning strengthens economic, strategic and organization structural bonding within organization and with organizational partners. Further, collaborative planning also enables several organizations in a specific sector or area to align their objectives and goals to achieve a common goal and allows them to effectively function towards that goal.

Healthcare services, access and delivery are fundamentally dependant on collaboration between multiple entities, both organizations and individuals. The healthcare service sector can be aggregated to a value chain of supply of the services from several sources to the individual users, patients or consumers (Porter and Teisberg 2004). The efficiency of this value chain depends on collaborative planning at several levels and in a variety of ways (Patel et al. 2000).

The first instance of use of collaboration in healthcare is for patient diagnosis, care and treatment at the clinic or hospital level. Often doctors, nurses and specialists have to align and coordinate their efforts to come to an agreed upon care and treatment strategy. In case of critical care or intensive care situations, this collaboration becomes even more difficult; and often has to be done without physical presence or verbal exchange of words (Xiao 2005). An example of collaborative planning in healthcare at the hospital or patient care level is when doctors and nurses collaborate in the treatment process using IT. The care team uses software tools for processes such as measuring, reporting and monitoring vital signs in real time; and exchanging data through mobile devices. Increasingly, evolving software and integration tools such as electronic health record systems and are being used for collaborative planning (Braa et al. 2007; Cunningham 2005).

A second instance of collaborative planning is in the healthcare research and development process. The healthcare research area operates within a complex chain of institutional and support mechanisms. For example, financial support from governmental and non-governmental sources is often obtained through a collaborative planning exercise between researchers and funders that establishes common ground for research priorities (Corser 1998; Dufault and Willey-Lesne 1999).

Third, collaborative planning supports clinical management, testing, and results reporting through pathology, radiology, electronic diagnosis systems etc (Von Korff and Gruman 1997). Clinical management for a particular disease involves collaboration, coordination and sometimes real time information exchange between organizations. Fourth, collaborative planning can result in a standardized approach to various medical functions. Common nomenclature methods, standardized practice, clinical guidelines, standards followed in the clinical functions are examples of the influence of collaborative planning followed by several organizations in healthcare and critical chronic illness management activities (Cunningham 2005). Finally, at a policy level, collaborative planning helps in surveillance and the control of diseases and epidemics. Policy and managerial objectives to mitigate such prevalence and mitigation of diseases are achieved through activation of suitable multi-stakeholder or multi-organizational initiatives and plans (Karsten 1999). Evidence for the use of collaborative planning and the use of IT for healthcare can be found in efforts to adopt a national health infrastructures by several countries (Pare, Sicotte and Jacques 2006; Van Der Meijden et al. 2003).

Information technology applications, tools and services can enhance the nature of collaboration and collaborative planning in a myriad of ways. IT systems facilitate the collaborative planning of organizations by allowing them to match goals and align processes with their partners. These systems are often a combination of project management software, groupware and collaborative software; which enable users to
organize projects and activities (Barlow, Johnson and Steck 2004; Ford, Menachemi and Phillips 2006; Miller and Sim 2004). These systems allow decentralized control and responsibility for overall plans and permit equal online access to all participants. They enable multiple individuals to be aware of task specification and track the results of the tasks. Similarly electronic clinical management developments using IT tools have created a paradigm shift in the clinical study, analysis and management areas (Roussos and Fawcett 2000). Along with enterprise systems and other tools in electronic-clinical tests, the deployment of e-clinical systems have improved the efficiency and decreased the time taken in clinical tests; thereby reducing lead time in the process of drug discovery and marketing. Extending beyond the single organization, there are also several multi-organizational and enterprise wide collaborative planning software suites that help multiple firms to coordinate and complete sophisticated projects. Finally, examples of collaborative planning for disease surveillance and control include the use of information and communication technologies for community health development (Khatri and Frieden 2002; Sarbadhikari 2005; UNAIDS 2007), control and eradication of diseases such as tuberculosis or AIDS in several countries (Galor and Moav 2005), and recent efforts in the US to track the incidence and spread of the H1N1 virus through information technology (Grady 2009).

In summary, three underlying mechanisms of information integration, workflow coordination, and collaborative planning are collectively responsible for the theoretical expectation that information technology spending at the country level will be associated with positive health outcomes. The empirical study to test this assertion is described next.

Method

We use internationally validated data compiled from multiple sources (e.g., the World Health Organization (WHO) and the World Bank) to address our research questions. While this study is associational in nature, to avoid reverse causality, we relate the data for our dependent variables captured in the year 2005 with that for the independent variables captured in previous years.

Variables

Life Expectancy

The health outcome in our model is captured by life expectancy, which is the average number of years of life remaining at a given age, conventionally calculated from the time of birth (Murray et al. 2002). The two variables lebirthmale2005 and lebirthfemale2005 measure the life expectancy of males and females for the year 2005. Life expectancy as an indicator summarizes the mortality pattern that prevails across all age groups - children and adolescents, adults and the elderly. It can be defined as the average number of years that a newborn is expected to live if current mortality rates continue to apply (Bone 1992; Gakidou, Murray and Frenk 2000). The data for this variable come from the World Health Organization (WHO), which in turn compiles it from various data sources, including those from the vital registration, census and surveys of the countries.

IT Investment

The IT investment is captured by the variable ictpcgdp2002, which reflects the information and communications technology expenditures as a percentage of GDP in the year 2002. This includes computer hardware (computers, storage devices, printers, and other peripherals); computer software (operating systems, programming tools, utilities, applications, and internal software development); computer services (information technology consulting, computer and network systems integration, web hosting, data processing services, and other services); communications services (voice and data communications services), wired and wireless communications equipments. The World Bank collates the data from several sources and with the help of organizations including the World Information Technology and Services Alliance, Digital Planet: The Global Information Economy, and Global Insight, Inc.
Control Variables

We control for several key variables that are likely to be correlated with our focal and dependent variable. We control for the total expenditure on health as percentage of gross domestic product for the year 2004 (totexpdhpcgdp2004), with an adjustment to the purchasing power parity at the international dollar rate. This variable serves as a proxy for healthcare Investment and infrastructure and comes from the WHO database.

To control for the disparity in health investment with respect to national income, we also include gross national income per capita for the year 2004 (gnpwww2004s), accounting for purchasing power parity.

We control for two variables that are a proxy for the health infrastructure and services indicators in a country. The human resource indicators - physician density (Hwphydens) and nurse density (Hwnursedens) provide the concentration of the physicians and nurses per 1000 population respectively, for the year 2004. Physicians include generalists and specialists; and nurses include professional nurses, auxiliary nurses, enrolled nurses and others, such as dental nurses and primary care nurses. The rationale for using these indicators is that the availability and composition of human resources for health is an important indicator of the strength of the health system. Although there is no consensus about the optimal level of health workers for a population, there is some evidence that the number and quality of workers are positively associated with immunization coverage, outreach of primary care, and infant, child and maternal survival. The data for these indicators comes from the WHO and statistical surveys, and are often generated from a multitude of sources and cover many areas (such as profession, level of training and industry of employment), establishment surveys, household and labour-force surveys, population and housing censuses and records from professional and administrative sources; and are harmonized taking into consideration several factors.

We control for the number of hospital beds per 10000 population (hopbed), another measure of the quality of healthcare infrastructure in a country. The hospital beds include in-patient and maternity beds. Maternity beds are included while cots and delivery beds are excluded. For hospital beds, WHO collects this data from administrative records of the country, based on reported data by in-patient facilities and censuses of health facilities. The method of estimation adjusts for underreporting (e.g. missing private facilities).

We also control for the population of the country in the year 2005 (pop2005s). The data for this variable come from the WHO database; but was originally collected from the United Nations Department of Economic and Social Affairs – Population Division. Figures are based on the most recent estimate or projection by the national census authority where available.

After combining data from all sources, we obtain 61 observations at the country level for which we had data on all variables.

Table 1 provides a summary of variable definitions and sources. Table 2 provides descriptive statistics for the countries in our sample. On average, countries have IT investment as percentage of GDP from 1.15% to 10.96% per year. In addition, the health investments of these countries are 2.2% to 11.5% of GDP per year. Life expectancy in the sample ranges from 59 years to 79 years for males, and 62 years to 86 years for females; with averages of 71.59 and 76.95 respectively for males and females.

Table 3 shows zero-order correlations for our model variables. Both IT investments and health investment have positive correlations with life expectancy of male and females. Other variables, with the exception of the population density, are also positively correlated with life expectancy. Total population of the country has a negative zero-order correlation with all other variables, suggesting that highly populated countries have lower per capita income, lower life expectancy, and invest less in IT, healthcare and complementary assets.

Empirical Models

To relate IT investments with healthcare outcomes, we specify standard cross-sectional models of the form
\[ Y_i = X_i \beta + \epsilon_i, \]  
(1)

where, \( Y \) represents health outcomes such as life expectancy; \( X \) represents a vector of independent variables, such as IT spending, total healthcare spending, income per capita; \( \beta \) are the parameters to be estimated; and \( \epsilon \) is the error term associated with each observation \( i \). We use ordinary least squares (OLS) to estimate our models. We tested for multicollinearity, and the highest variance inflation factor value of 4.10 suggests that multicollinearity is not a serious concern in our analyses.

Results

Table 4 reports results of OLS estimation. IT investments show a positive and statistically significant association with male and female life expectancy. The association is stronger for males, than for females (male, \( \beta = 0.468 \ p < 0.01 \); female, \( \beta = 0.343, p < 0.1 \)). In substantive terms, the results indicate that there would be an average increase in life expectancy of 5.6 months for males and 4.1 months for females for a 1% increase in the IT investment as a percentage of GDP.

The total expenditure on health is also significantly associated with life expectancy (male, \( \beta = 0.503 \ p < 0.05 \); female, \( \beta = 0.340, p < 0.1 \)). There would be an average increase in life expectancy of 6 months for males and 4 months for females, with 1% increase in the health investment as percentage of GDP. Further, we find that the per capita gross national income is significant on the health outcomes, indicating that the developed countries have higher life expectancy.

Among other results, physician density is positive but statistically non-significant. Surprisingly, nurses’ density shows a negative impact on life expectancy, suggesting that, on average, increasing the number of nurses holding other things constant may not improve life expectancy.

We conducted additional analyses for robustness checks. First, because female enrollment in primary school may be correlated with IT investments and life expectancy, we included that as a control variable in our models and our results remain broadly similar (IT is statistically significant in one-tail tests at p<0.10).

Second, results remain unchanged even if we include a control for population below poverty line in our models.

Third, we included an interaction term involving GNP per capita and IT expenditures in our models to investigate if IT investments have differential effects on life expectancy in rich versus poor countries. The interaction term was statistically insignificant, suggesting that IT investments have similar effects across countries in our sample.

Discussion

The goal of this study was to assess the association between IT investments and life expectancy at the country level. We find significant support for the influence of IT investment on both male and female life expectancy. In other words, more IT intensive countries have higher life expectancy. The life expectancy increases by approximately half a year for 1% increase in IT investment of GDP. We also find that IT has greater impact on life expectancy of males, than that of females. Higher investments in healthcare are also associated with greater life expectancy. The life expectancy increases by approximately half a year for 1% increase in healthcare as a percentage of GDP. Countries with higher GNP per capita have higher life expectancy.

How should one interpret the findings of this study? One plausible interpretation of our findings is that countries that spend more money on IT achieve higher life expectancy because greater infusion of IT in a country enables information integration, workflow coordination and collaborative planning among various stakeholders involved in healthcare planning and delivery. An alternative and rival explanation for our findings can also be that wealthier countries spend more money on complementary assets and infrastructures, along with IT and health; which are reflected in higher life expectancy. To the extent we control for some of the key variables that are correlated with both IT investments and life expectancy (e.g.,
GNP, physician density, hospital beds), our study provides some support for the assertion that IT can potentially improve health outcomes.

Before we discuss what these findings imply, some limitations of this study should be kept in view. Because of the unavailability of data on healthcare related IT investments at the country level, we used a proxy, that is, overall IT expenditures of a country with the assumption that country level IT expenditures will capture between-country variations in deployment of IT in healthcare. Likewise, while we control for many important control variables that are likely to be correlated with the key explanatory variable and the dependent variable, other social, historical, cultural, political, geographic or economic factors for which we do not have data may affect the relationship of interest. Because of these data limitations and the use of a cross-sectional design, our results indicate an association and should not be given a causal interpretation (see Mithas and Krishnan 2009 for a discussion of causality related issues). Furthermore, we focus on only one health outcome (i.e., life expectancy) and there is a need to look at other health outcomes to draw more robust and generalizable conclusions. Despite these limitations, the findings are useful and provide an initial estimate of the relationship between IT expenditures and life expectancy at the country level that is informative from a policy perspective.

In terms of policy implications, this study provides an order-of-magnitude assessment of the link between IT spending and life expectancy at the country level. The findings can help policymakers to prioritize their resource allocation decisions by comparing the efficacy of IT investments in different areas that may be of concern. While IT can improve health outcomes, any large scale funding initiatives must be justified based on evidence and evaluated vis-à-vis other important policy initiatives that may have equal or greater impact. For example, if IT has greater shorter-term impact say on educational outcomes, which may in turn improve both economic well-being and health outcomes, then policymakers are better off focusing their IT investments in the education sector than in the healthcare sector. Alternatively, if female primary school enrollment influences healthcare outcomes positively and it is more cost effective to increase female primary school enrollment than investing IT dollars in healthcare, then governments and societies are better off allocating their scarce resources to education because such investments may also improve many other outcomes that societies care about.

A related issue is whether higher life expectancy is necessarily a desired outcome in all countries. Given that many developed economies already have generally higher levels of life expectancy and if a further increase in life expectancy is accompanied by a deterioration in quality of life towards the end, then any increased investments in IT to increase life expectancy may not be beneficial from an individual or a societal perspective. While there may be a need to improve healthcare infrastructure in developing countries that currently have extremely low levels of life expectancy through higher investments in IT and related complements, it may very well be that developed economies need to think of containing their healthcare costs primarily through policy interventions that align incentives in the healthcare value chain.

Irrespective of the development status of a country, while IT can play an important role in reducing administrative costs and streamlining business processes, government can play a more effective role by aligning incentives of various stakeholders such as hospitals, patients, doctors and encouraging use of newer technologies and platforms that foster open collaboration (e.g., through use of open standards and open source approaches) and help lower costs in administrative and clinical processes. Several studies and media reports (Herzlinger 2006; Herzlinger and Millenson 2008) have highlighted conflicts of interest and misaligned incentive structures that eventually reflect in lack of access to healthcare to a large segment of population, and a concern that insurance companies may deny even genuine services in pursuit of profit at the expense of patients. Given that the US spends much more than other developed countries on healthcare as a percentage of its GDP without a corresponding increase in aggregate measures of health outcomes, policymakers need to evaluate investments in IT along with other policy choices they have. An overinvestment in IT without changes in incentive structures and business processes can worsen the situation even further if issues related to incentives and patient privacy are not adequately addressed.

The findings of the current study have implications for further research. First, while we show that IT intensity of a country is positively associated with higher life expectancy, it will be useful to link IT
investments with other health outcomes to validate our findings and to provide more fine-grained results for policy-makers to make informed decisions with respect to allocation of IT resources in healthcare area.

Second, this study explored how IT investment of a country directly affects health outcomes. This effect, however, is likely to be mediated by other measures such as better quality of healthcare or better access to healthcare. Although we proposed three mechanisms linking IT with healthcare, future research should operationalize and measure these mechanisms, and directly study the mediating impacts. Studies at the regional, hospital or system level may be better suited for directly testing the validity of the mechanisms proposed here. There is also a need for identifying and operationalizing other intermediate measures to elaborate more completely the causal chain linking IT with healthcare outcomes.

Third, the relationship between IT-enabled information integration, workflow coordination and collaborative planning is likely to be moderated by other factors such as overall education levels, form of government (centralized versus decentralized), and economic environment (capitalist versus socialist). Studying these moderating effects will provide a more complete understanding of when and how strongly IT may influence healthcare outcomes.

Finally, beyond the health care sector, IT can also be directed to address the barriers to development (e.g., lack of social mobility, illiteracy, and poverty) -- there is a need for research on how IT can be deployed to address and alleviate these aspects. There is also a need to focus on community informatics, a field that links economic and social development efforts at the community level with emerging opportunities offered by IT, and takes into account the perspective of the to-be-affected communities in understanding the IT impact.

In conclusion, this study provides one of the first empirical tests to assess how IT investments at the country level are associated with life expectancy at the country level. We proposed three mechanisms (e.g., information integration, workflow coordination and collaborative planning) to explain why IT may be related to health outcomes, and show that higher IT investments at the country level are associated with higher life expectancy. These contributions open new avenues for linking IT with intangible but valuable outcomes such as better health and improved quality of life.
Table 1. Variables and Data Sources

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definition</th>
<th>Source</th>
</tr>
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<tbody>
<tr>
<td>lебirthmale2005</td>
<td>Life expectancy at birth of males in number of years</td>
<td>World Health Organization</td>
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<tr>
<td>lебirthfemale2005</td>
<td>Life expectancy at birth of females in number of years</td>
<td>World Health Organization</td>
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<td>ictpcgdp2002</td>
<td>Information and communications technology expenditures as percentage of GDP</td>
<td>The World Bank</td>
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<td>hwphydens</td>
<td>Density of physicians per 1000 population</td>
<td>World Health Organization</td>
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<tr>
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<td>Density of nurses per 1000 population</td>
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<tr>
<td>pop2005mn</td>
<td>Total population of the country (in millions)</td>
<td>United Nations Department of Economic and Social Affairs</td>
</tr>
<tr>
<td>gnpppp2004x</td>
<td>Gross national income based on purchasing power parity per capita in international dollars.</td>
<td>World Health Organization</td>
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</tbody>
</table>

Table 2. Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
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<tbody>
<tr>
<td>lебirthmale2005</td>
<td>61</td>
<td>71.59</td>
<td>5.38</td>
<td>59.00</td>
<td>79.00</td>
</tr>
<tr>
<td>lебirthfemale2005</td>
<td>61</td>
<td>76.95</td>
<td>5.60</td>
<td>62.00</td>
<td>86.00</td>
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<tr>
<td>ictpcgdp2002</td>
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<td>5.85</td>
<td>2.07</td>
<td>1.15</td>
<td>10.96</td>
</tr>
<tr>
<td>hwphydens</td>
<td>61</td>
<td>2.06</td>
<td>1.25</td>
<td>0.13</td>
<td>4.49</td>
</tr>
<tr>
<td>hwnursedens</td>
<td>61</td>
<td>5.01</td>
<td>4.22</td>
<td>0.14</td>
<td>15.20</td>
</tr>
<tr>
<td>totpexpdhpcgdp2004</td>
<td>61</td>
<td>6.95</td>
<td>2.26</td>
<td>2.20</td>
<td>11.50</td>
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<td>hospbeds</td>
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<td>40.90</td>
<td>29.61</td>
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<td>129.00</td>
</tr>
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<td>15460.66</td>
<td>11159.81</td>
<td>1980</td>
<td>38550</td>
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<td>pop2005mn</td>
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<td>78.98</td>
<td>217.14</td>
<td>0.10</td>
<td>1323.35</td>
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### Table 3. Correlation among Variables (N=61)

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<thead>
<tr>
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<th>1</th>
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<th>4</th>
<th>5</th>
<th>6</th>
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<th>8</th>
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<tbody>
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<td>4</td>
<td>hwphydens</td>
<td>0.53</td>
<td>0.67</td>
<td>0.05</td>
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<td>0.61</td>
<td>0.11</td>
<td>0.67</td>
<td>1.00</td>
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<td>6</td>
<td>toexpdhpcgdp2004</td>
<td>0.64</td>
<td>0.67</td>
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<td>0.72</td>
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<tr>
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<td>0.13</td>
<td>0.58</td>
<td>0.52</td>
<td>0.41</td>
<td>1.00</td>
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<tr>
<td>8</td>
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<td>0.84</td>
<td>0.83</td>
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<td>0.84</td>
<td>0.66</td>
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<tr>
<td>9</td>
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<td>-0.32</td>
<td>-0.20</td>
<td>-0.23</td>
<td>-0.23</td>
<td>-0.17</td>
<td>-0.24</td>
</tr>
</tbody>
</table>

All correlations greater than 0.25 are statistically significant at p<0.05.

### Table 4. Information Technology and Life Expectancy

<table>
<thead>
<tr>
<th>(1)</th>
<th>(2)</th>
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<tbody>
<tr>
<td>lebirthmale2005</td>
<td>lebirthfemale2005</td>
</tr>
<tr>
<td>ictpcgdp2002</td>
<td>0.468*** (0.004)</td>
</tr>
<tr>
<td>hwphydens</td>
<td>-0.424 (0.321)</td>
</tr>
<tr>
<td>hwnursedens</td>
<td>-0.580*** (0.000)</td>
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<tr>
<td>toexpdhpcgdp2004</td>
<td>0.503** (0.019)</td>
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<tr>
<td>hospbeds</td>
<td>-0.006 (0.617)</td>
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<tr>
<td>gnpppp2004x</td>
<td>0.001*** (0.000)</td>
</tr>
<tr>
<td>pop2005mn</td>
<td>-0.001 (0.630)</td>
</tr>
<tr>
<td>Constant</td>
<td>61.063*** (0.000)</td>
</tr>
<tr>
<td>Observations</td>
<td>61</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.833</td>
</tr>
</tbody>
</table>

p values in parentheses,
*** p<0.01, ** p<0.05, * p<0.1
References


Lohr, S. "Doctors Raise Doubts on Digital Health Data: Concern that Effort May Not Improve Care," New York Times (March 26) 2009, p B3.


Surowiecki, J. *The wisdom of crowds: Why the many are smarter than the few and how collective wisdom shapes business, economics, societies, and nations* Doubleday, New York, 2004.


